SCIENCE

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THE NATURE AND PURPOSE OF EDUCATION[1]

Students of Michigan: From farm, village and city, from every state in the union, from every continent in the world, you have come to spend here from four to six years in the formative period of your lives. Why are you here? What has impelled you to leave your homes and come to this small city? While Ann Arbor is a pleasant place in which to reside, there are many other cities, both larger and smaller, more attractively located. We have no inspiring view of ocean, no picturesque lake, no majestic river, no towering mountain peaks, no vine-clad hills, no broad valleys, no historic associations, no ruined castles. Ann Arbor is a commonplace town, pleasant enough in its way, but without the material attractions of which a hundred other places may boast. What is the loadstone that has drawn you from near and from afar? It is the university. What is the university, why does it exist and what is your purpose in coming to it? Some universities have been founded to perpetuate theological creeds, some to serve as monuments to men of wealth and power, but neither of these motives actuated the founders of this university. It had its inception in the wisdom of the early settlers of this state, it has been and is maintained by the labors of their descendants. The rich and the poor contribute to its support. Many of the former send their sons and daughters to more aristocratic institutions and many of the latter are not able to send their children to any university, but all pay in proportion to their means to the support of this institution. What justifies the people of this state in imposing upon themselves the burden of taxation necessary to sustain this university? The total fees paid by

[1] A popular lecture to the students of Michigan University on Convocation Day, October 16, 1914.

you each year would not carry the current expenses for three months. The people of the state are, therefore, giving each of you more than four times what it received from you. Each of you becomes a debtor to the state. What does the state demand from you in return for its generosity? There is an implied moral contract between each of you and the state, and unless you intend to comply with your obligation to the state you should not be here. The university does not exist in order to support the saloons and billiard halls of this town nor to afford a comfortable residence for loafers, and the university authorities are not worthy of the trust imposed upon them if students of this class are permitted to remain here. This is not a reformatory institution, nor is it an asylum for the feeble-minded, the state having made provision elsewhere for those wanting in morality and intellectuality. Admission is a privilege and continued residence should be permitted only to those who show intelligence, industry and integrity in all proper functions of student life. Even admonition to more earnest work or better behavior is not a duty of the university teacher to his students. The purpose of the university is to better fit you for citizenship. With this end in view, the people of Michigan expend on you more than one million dollars annually, a sum which if capitalized at four per cent. represents twenty-five millions. This means that the amount annually paid for the support of this university is equivalent to a contribution of more than one third of a dollar from every inhabitant of the state. Is this expenditure justified? Why should the state be so generous and what obligation do you assume in accepting this generosity? If there be among you those who do not feel any responsibility in this matter, in all honor let such depart immediately. The state does not educate you in order that you may make a living more easily. It does not intend to make shyster lawyers, who fleece their clients, nor quack doctors who rob the sick and afflicted, nor ignorant engineers who build unsafe bridges, nor indifferent school-teachers who perform their tasks perfunctorily, nor lazy farmers who impoverish the soil; but it does hope to educate jurists who will see that only wise laws are enacted and in their administration justice shall be done, physicians who will render the sick the best service and protect the well from disease, engineers who will develop the natural resources, school teachers who will train the young in body and mind, and farmers who will improve the fertility of the soil. The state realizes that intelligence, industry and integrity are the great factors in the betterment of the conditions of life and it seeks the development of these attributes in all its citizens. In a generous spirit it offers its training in these qualities to all who are capable of development along these lines whatever their nationality, color or creed may be. One who is lacking in any one of these cardinal virtues can not be of service to the state and should not seek his education in a state university. Without intelligence development is impossible; without industry life is barren; without integrity the individual is a menace to the state.

In a broad sense, education has been defined as the modification and development of behavior through experience. Since behavior is determined through the mechanism of the nervous system, education is concerned especially with the function of the nerves. Man comes into the world the most helpless of all animals. At birth the child is incapable of locomotion and of finding unaided its food supply. For months, and indeed for years, the child remains in this helpless state. The dog in the first six months of its life learns more than the child does in years. It is the superiority of his nervous mechanism that has given man dominion over the earth and all that is therein. We need sound bones, strong muscles and healthy organs, because these render the development of the nervous system possible, and the health of the body, as a whole, is essential to the well-developed man. We can have no correct conception of education without some knowledge of the mechanism employed in its acquisition. Briefly considered, the nervous system consists of receptors or special senses, which are stimulated by the

environment, of conductors which transmit the stimulation to the central organs and of effectors which control and direct the responses to the stimuli. The primary function of the nervous mechanism is to provide paths of conduction between the receptors and effectors. The first breath of air at birth starts the machinery of respiration. Irritability and automatism are properties of all living things. Even unicellular organisms, amebæ, for instance, in which there is no nervous tissue, automatically respond to external stimuli, such as food, and changes in behavior or rudimentary and limited education can be developed in them. As cell differentiation is evolved the structure of the nervous system becomes more complicated and its functions are more diversified and effective.

A sense receptor, such as the eye or ear, the sensory nerve, such as the optic or the auditory, the nervous center to which the impression is conveyed and the motor nerve, through which the response is transmitted, constitute the "reflex arc." Reflex action is the simplest function of the nervous system. Strong light induces contraction of the pupil, the sight or odor of food causes the saliva to flow, pinching the flesh is followed by muscular movement. These are examples of innate reflexes. The normal child comes into the world possessed of these reflexes. A large part of education consists in the coordination and development of these innate reflexes. Walking, talking, reading, writing, are examples of coordinated, trained reflexes.

The first lesson we learn in investigating the mechanism of education is that the sense receptors must be in good condition to start with and must be kept in the highest state of efficiency as we proceed. The receptors through which our behavior is modified and developed by environment are the five senses, seeing, hearing, touch, smell and taste, each of which, on close analysis, is found to be complex. All primary knowledge reaches the brain through these sources. In no other way can environment modify our behavior or can we be educated. The dictum of Locke, "Nihil in intellectu est quod non prius in sensu," is not refuted by the addendum of Leibnitz, "Nisi intellectus ipse." When the senses are defective in function, illusions, hallucinations and delusions control us and dominate our conduct. The senses may be primarily defective and to some extent these defects may be removed by medical skill. When normal in mechanism these functions may be impaired by poisons introduced from without the body, such as alcohol, or by those generated within the body, such as those due to fatigue or to disease. Although the truth expressed in the Latin proverb, "Mens sana in sano corpore," has come down to us from classical times, educators have been slow to realize its force. Indeed, when mystical scholasticism formulated educational ideals affliction of the body was believed to be essential to the highest development of the mind. Fortunately, even educators, one by one, with some reluctance, are awakening from their dreams and becoming interested in scientific investigation. Greater benefits in educational methods have been obtained by observation of the effects of altered environment on the behavior of animals than have been evolved from the inner consciousness of the greatest genius. Appreciating the fundamental importance of normality in securing an education, this university is developing a splendid system for the supervision of the health of its students. However, the health of each individual is largely in his own keeping, and I wish to say that idleness, alcoholism and sexual vice remain the most potent factors in student wreckage. With senses untrained from idleness and benumbed by dissipation, the individual is a failure in college and in the greater school of the world.

Certain complex reflexes are known as instincts. These play an important part in education. All instincts are not manifest at the time of birth, but develop with age and are influenced by the evolution of the individual, as a whole. The instinct of play manifests itself in every normal child and the same is true of the instincts of acquisitiveness, construction, possession, self-assertion, anger, self-abasement, rivalry, pugnacity, etc. These

need to be controlled and directed, and this constitutes an important part of education. They are inherited, but are subject to marked modification by environment. For instance, the instinct of imitation is one of great potency in shaping our conduct and in determining not only our own lives, but of those about us. In this lies sufficient justification of state education. One scientific farmer in a community enhances the value of all the farming land about him, because he demonstrates the productivity of the soil. One honest, learned lawyer reduces litigation and a skilful physician not only alleviates the suffering of the sick, but prevents the spread of disease. The highest purpose of this university is to train leaders of men, those whose influence among their fellows may always be in the right direction.

Success will depend largely upon the environment under which you live while here. This can not be wholly determined by the university authorities. To a large extent you will educate one another.

A part of education consists in inhibiting reflexes and suppressing misdirected instincts. The only way in which this can be done is by the cultivation and exercise of certain other reflexes. As we shall see later, nervous impulses travel most easily over well-worn pathways. A function frequently performed proceeds automatically and to the exclusion of antagonistic tendencies. One of the most difficult things the untrained student has to contend with is diffuse activity. He tries to study, but outside stimuli of vision, hearing, etc., bombard his sensorium and demand his attention. Training is essential before calls to purposeless activity can be ignored.

The first impression which one receives in studying the structure and function of the nervous system is that it is a grossly defective mechanism. The elements of which it is composed consist of nerve cells with axons and dendrites. The dendrites are supposed to receive the stimuli and the axons to conduct them to the next unit. Between these units, called neurones, there is no direct structural connection. The axons of one unit come in more or less direct contact with the dendrites of the next, but each neuron is organically quite distinct from all others. The apparent imperfection lies in this absence of direct connection. The point of contact between two neurons is known as a synapse and at this point there is more or less resistance to the transmission of the stimulus. This apparent imperfection is, however, in some respects at least, a benefit. Were it not for this delay the brain would be stormed continuously by stimuli from the outer world and orderly thought would be quite impossible. Without these apparent imperfections, sleep would be less restful and anesthetics would not be able to relieve pain. Education consists partly in improving these connections. A pathway through the nervous tissue having been once opened is more easily followed by subsequent similar stimuli. This renders possible the formation of habits. The more frequently a given pathway is traversed, the more easily stimuli pass, until finally transmission occurs without conscious effort. The first attempt to learn is more or less laborious, but with each repetition the resistance becomes less and finally the thing is done automatically. Effectiveness is largely the result of the formation of good habits. In this way the expert is developed. The best preparation for doing anything is the fact that you have once or oftener done it, and the more frequently it has been done the more certainty is there in repeating it. The beginner in telegraphy must give attention to each letter, then he thinks only of words, and later he advances to phrases and even to sentences.

In learning of this kind, progress is not always uniform. After reaching a certain degree of proficiency there is a period in which there is no apparent progress. These periods are known as plateaus. All students are familiar with these depressing states in which effort seems without avail, but with persistence the curve of learning suddenly begins to rise and the elation of success is the reward.

The question of the transference of skill acquired in one branch of learning to another has been debated among psychologists, but the

weight of evidence is that it is not possible. Being an expert mathematician does not make one an authority in law or medicine. The neural pathways opened up in the pursuit of different branches of learning are not the same. They may lie quite far apart and expertness in one line does not imply even soundness of judgment in another. This is an important matter in education and will receive further attention later.

The formation of habit is common to all animals, and habits have a marked influence on behavior. We do things so often that it becomes difficult to refrain from doing them when the conditions under which they have been done recur. The most forceful teacher of my college days was wont to say: "Man is but a bundle of habits and happy is the man whose habits are his friends." At twenty, it seemed to me that the force of this saying lay in its sonorous quality. At sixty I realize that its strength lies in its truth. The young scout the idea that they can not indulge in a vice occasionally without becoming a victim. The chains forged in the smithy of habit are strong in every link. They may safely hold us in the heaviest storm or they may drag us to the bottom of smooth seas. Another mistake often made by youth is the belief that every experience is helpful. There is no other commodity for which we pay so dearly and the price often is health, happiness and even life.

Some stimuli make such deep and lasting impressions on the central nervous system that the picture may be recalled without the recurrence of the original stimulus. This is memory. Jennings has shown that there is some evidence of memory even in unicellular organisms. This becomes more marked as the animal structures, especially the nervous system, develop. Even a spider learns by experience and alters its behavior to its own benefit, when repeatedly subjected to like conditions.

Colvin says:

> Memory is a fundamental phenomenon of organic life. In its widest sense it signifies the fact that impressions once received by an organism are retained for a greater or less period and that this retention is indicated in the modified behavior of the organism. The evidence of memory in animals is their ability to profit by experience. A white rat is placed at the entrance of a maze at the center of which is food. The animal moves about in an aimless manner until at length it reaches the center. If on succeeding trials the rat shows an improvement in the accuracy and rapidity with which it moves about the maze, this means that its earlier attempts have in some sense left their effects; they have modified subsequent conduct. Memory, when used in this widest sense of the term, lies at the basis of all learning. It is a measure of educability.

There are three important factors in memory. The impression must be "stamped in." It must be correctly associated with other impressions. It must be subject to recall and proper recognition. The strength of the impression is dependent upon many factors. The brain may be so altered by inherited defect, trauma, senility, fatigue, disease or toxic agents, that effective and lasting impressions can not be made. So long as the brain remains in the abnormal condition its receptivity can not be improved. The mentally defective can be educated to a certain point, but can go no farther. An impression may be "stamped in" by the force or unusual character of the external stimulus. The external world demands the attention of the individual and an unusual sight, noise or other sensation makes a never-to-be-forgotten impression. This is known as passive attention and is common to all animals. It is the basic principle in all attempts to modify behavior through hope of reward or fear of punishment and is highly effective in the control and training of the lower animals and ignorant men, but loses in power with the development of intellect. However, in this and other universities this appeal to increased effort is employed in the form of grades, admission to special societies, the bestowal of insignia of distinction, etc., and on most men in our stage of development it is not without effect. The approval of our fellows as shown by social, political and intellectual preferment, still proves a potent incentive to increased effort. With the development of intellect, passive attention is largely supplanted by the active form. In

the latter the individual selects the stimuli which are to make permanent impressions. An important function in the accomplishment of this purpose is the rejection of stimuli believed to be unimportant or harmful, and seizing upon and fixing of those recognized as of greatest value. In this selection lies the pathway to wisdom. It determines the ideals of the individual. It shapes the ego and sets the lines of future development. The memory pictures photographed in the highly labile molecules of the brain constitute a record of all our available knowledge, not only that gained through personal experience, but that acquired from any source. We rehear the spoken and reread the written word. We recall the facts of history. We utilize without conscious effort in our daily dealings the mathematical skill acquired in childhood. We make practical application of the scientific discoveries of the past in supplying ourselves with the necessities and comforts of life. We enjoy the literature of all nations in all ages. In short, the storehouses of learning to which we have access are practically limitless in their wealth, and from this we may select at will and appropriate to our own use without diminishing to the smallest degree what is left for others.

In order to be of greatest service, memory pictures must be clear and properly placed. Clearness and association are essential to prompt recall and correct recognition. Memory, like all other functions of the nervous mechanism, is capable of improvement by exercise. When memory pictures have a faulty setting, they may influence behavior disastrously. The old man thinks all this talk about impure milk killing infants and infected water causing typhoid fever is nonsense, because all his life people, both young and old, have been drinking dirty milk and polluted water. He does not know or recognize the fact that many even within his own circle have died from these causes. In his experience these facts have not been recognized as possessing any causal relationship. Half his children have died from the summer diarrheas of infancy and others have died in youth from typhoid, but he has always connected these bereavements with the world-old belief that disease could not be prevented nor death delayed. The failure to properly correlate experiences or their memory pictures is one of the things which prevent many elderly people, especially the untrained, from adjusting themselves to advances in knowledge. Many superstitious rites and ceremonies have their origin in the faulty conception of cause and effect. Many reason post hoc ergo propter hoc. This faulty logic is still a strong support of charlatanism in its many survival forms.

The study of the structure and function of the nervous mechanism makes plain what should be attempted in securing an education. We have seen that in the acquisition of knowledge pathways to the cerebral cortex must be opened up. Conduction of nervous impulses meets with resistance as it passes from one neuron to the next. This resistance grows less with each traverse of the impulse along the same path, and with frequent repetition the trail becomes so smooth that impulses pass through without conscious effort. It is easier to open up pathways to the cortex in youth than in later years because the lability and plasticity of the nervous tissue decrease with advancing age. However, lines of conduction established in the plastic period are never obliterated save by disease or death. Even with approaching senility, when the opening of new lines is impossible, those established in youth continue to operate. Truly, learning becomes the solace of age. The educated octogenarian remains in sympathy and intelligent touch with the outer world, while his untrained brother finds himself isolated and marooned on a small barren island. Furthermore, it has been demonstrated that the lines of conduction which serve in one department of learning are useless in the conduction of information from other sources. The acquisition of mathematical skill does not give special preparation for historical erudition. These elemental psychological facts indicate that in youth training of the nervous system should be broad, the purpose being to estab-

lish many and diversified sources for the supply of mental pabulum. Symmetrical exercise is as essential to the normal development of the nervous system as it is in muscular training. Athletes are not made by putting all muscles save one in plaster casts and exercising the free one, neither can the functions of the brain be properly developed in such a way.

What are the fundamental subjects which should form the basis of education? It goes without saying that the educated man must know his own language thoroughly. He should possess a large vocabulary and should select his words and shape his phrases and sentences with reference to smoothness of diction and clearness of statement.

Language is the medium of exchange in mental commerce and it must be on a gold basis. Fortunately in this country dialects are not sufficiently developed to interfere with intelligent transfer of information. However, we are known for our diversified richness in slang. Some of these expressions are highly illustrative of multum in parvo in speech, sound in sense, rich in humor and forceful in meaning. The function of the educated man in regard to these colloquialisms consists in the suppression of the atrocious ones and the regulation of others. Next to color, speech is most powerful in fixing dead lines across the paths of individual advancement and usefulness. A man who is constantly blundering in the use of his native language can not be long tolerated among the educated, whatever his virtues may be. In European countries, dialect is a potent factor in class distinction. I never fully appreciated this until I met with the following experience in southern Italy. On a drive I saw a beautiful villa, picturesquely situated, quite new and untenanted. On my return to the hotel I asked an intelligent appearing man concerning the villa. He became quite excited and in broken, but plainly intelligible English he made the following statement: "I was born a peasant in this community. I never spoke Italian and knew only the local dialect. At sixteen I went to New York. During the forty years of my residence in that city my highest ambition was to accumulate enough wealth to enable me to return to Italy and to participate in its affairs, concerning which I kept myself thoroughly posted. Four years ago I closed my business in New York and returned to this place. My dreams were now to be realized. With much pride I purchased land and built the villa you have seen. But the moment I attempted to move in economical, social or political matters, I found a dead line I could not cross. I did not speak Italian. I do not blame those who repulsed me. You would not have at your table an American who did not speak correct English. In New York I spoke only broken and incorrect English, but all said Mr. Blanco is Italian and we do not expect him to speak correct English. The villa can rot. I am going back to New York." Even in this country and in university circles I have known men who show lack of fundamental education by lapses in speech. Some years ago I was called one morning into the country where a German farmer asked me to lance a "bile" on his arm. On my return to town I saw a university instructor who told me that he had been vomiting "boil" all morning. A temporary colleague of mine, a man of much merit, frequently said: "I done it." Another said: "them there things." It is needless to add that these men found themselves out of place in a university faculty. There is one peculiarity about men of this kind; they are infuriated at the most delicate attempt of a friend to help them in their defects. Every educated man should speak and write correctly by habit.

The study of Greek and Latin is a great factor in the comprehension of other languages partly derived from these. Moreover, one who is limited in his reading to translations, whether the original be in ancient or modern speech, loses much of the force, beauty and spirit of the author. It is true that there are translations which equal and a few which improve the originals. As one who has made scientific work his special endeavor during the entire period of his adult life, the speaker believes that the student who has

never dug Greek roots nor pruned Latin stems has missed much in both pleasure and discipline. If a bit of personal experience be permitted, the speaker testifies that the first author to quicken the pyramidal cells of his cortex was Virgil, and to-day when recreation is sought the only book preferred to Virgil is Dryden's translation of the same.

While an educated man's linguistic ability may be limited to English, inability to read French and German handicaps him, delays acquaintance with important discoveries in various realms of knowledge, and limits his mental vision. To scientific workers a reading knowledge of French and German is quite essential. There are splendid nuggets of science and glittering gems of imagination encased in Italian, and sparkling jewels of humor encrusted in Spanish, but these, with many other languages, both ancient and modern, can hardly be placed in the list of educational essentials, however important they may be to the special student or for direct vocal intercourse. When philologists grow away from the false idea that centuries are necessary for the development of effective language and when nations recognize that there is no need of limiting verbal and written intercourse by political boundaries, man will use a world language, more perfect in structure, more forceful in expression and elegant in diction, than any now used. This time, like that of universal peace and good will, now seems a long way in the future.

Man needs figures as well as words. His sense perceptions are registered in numbers. They take various shapes. He perceives not only plain surfaces, but extension in geometrical forms. He needs figures in all his mental concepts. Some of the lower animals can count in small figures, while those of man are unlimited. He must establish units of measurement, linear, square and cubical. The external objects which stimulate his sense organs and photograph themselves on the sensitive plates of his brain vary in number, shape and size. Every educated man should know mathematics through plane trigonometry.

History is a record of the experiences of past generations and of these no man can afford to be ignorant. The child comes into the world without inherited knowledge and the individual can not depend upon his own narrow and limited experiences. The brute has this to direct and modify its behavior, and we have enough of the brute disposition left in us to make us slow to profit by the experiences of others. This is a marked defect in youth. The young man believes that he can take personal, economic and social risks in which thousands of others have fallen, without injury. He believes that he was born under a propitious star, trusts his luck and goes to ruin by the same path that others have traveled and that more will continue to travel. If this were true only of individuals, it would not be so bad, but it is equally true of nations or rather of those who control nations. Some man, laboring under the delusion that he is a chosen son of destiny, brings about some horrible catastrophe which results in death, sorrow and suffering to the present generation and places chains of bondage on the unborn.

I have defined education as the modification of behavior by experience, and a large part of this experience which is to determine our behavior should be learned from history. History in the wide sense in which I am now using the word includes the record of all human experience. It is national, communal and individual.

Fuller says:

> History maketh a young man to be old without either wrinkles or gray hair; privileging him with the experience of age, without either the infirmities or inconveniences thereof. Yea, it not only maketh things past present, but enableth one to make a rational conjecture of things to come. For this world affordeth no new accidents, but in the same sense when we call it a new moon, which is the old one in another shape; and yet no other than it hath been formerly. Old actions return again furbished over with some new and different circumstances.

Failure to profit by the experiences of the past leads to the most serious disasters that befall our race. Study history. Study it in college and out of college. Devote much of your energy to it in youth, find time for it in

your busiest years, and do not neglect it in age. For if it maketh the young old without infirmity, it keepeth before the old the pictures of the eternal youth of the race.

There has been some discussion among partisan educators about the relative merits of humanistic and scientific studies. The symmetrical and effective development of the nervous system demands both forms of exercise. The man who knows the classics and nothing more is blind and deaf to much which is of the highest interest to both himself and his fellows. The man whose knowledge is confined to some narrow domain of science is equally out of touch with much that is necessary to make life rich in either endeavor or accomplishment.

Without experimental science man would be to-day in his primitive state, or more likely he would have become exterminated long since in his unequal contest with the elements and the brute creation. Even in his most perfect physical development he is inferior to many of the lower animals in muscular strength, fleetness and range of sense recognition; but he is unique among animals in the development of the instinct of inquisitiveness. He wants to know, therefore, he experiments. He observes the effect of altered environment, and his interest in experimentation grows in scope and purpose. He ascertains that when certain definite relations are established, the results are constant. He slowly develops an appreciation of causal relationship. After countless generations of crude experimentation, careless observation and faulty generalization, he sees the necessity of greater exactitude in his experimentation. In this way, slowly and laboriously, the sciences have been evolved. With periods of barrenness of variable length, some of which have extended through many consecutive centuries, man has slowly progressed from his primitive state to his present condition. Scientists, the greatest benefactors of the race, have always been few in number, but their work has benefited many. In some ages the masses have been too ignorant to utilize the scientific knowledge possessed and enjoyed by their ancestors and have shown marked retrogression. The most potent causes of these lapses have been disease, war and famine. In no age, not even the present, has scientific training touched more than a small part of the generation.

Some primitive man learned that fire could be kindled by friction between pieces of wood or that a spark could be struck with flint. What benefit came from this simple discovery? It gave protection from the cold of winter and greatly extended the range of man's activities. The camp fire, now started when and where he willed, frightened away beasts of prey, served to cook his food and formed the nucleus of a primitive home. One day, ore being used as stones for the crude hearth, metal is found in the ashes and the flint age is passed and that of metal has come. Century after century passes; accidental discovery is replaced by systematic investigation, and the science of metallurgy with its multiple benefits is developed.

Primitive man crouched in terror when darkness enveloped the earth at noon day. He could see in this only the angry disapproval of an all-powerful God. The stars were supposed to control the destinies of individuals, communities and nations. The motions of the celestial bodies were observed, the heavens were charted and astrology became astronomy.

Primitive man fed upon such fruits, vegetables, nuts and berries as the soil gratuitously offered him, eked out with the uncertain product of the chase. Experience showed that the productivity of the soil would be greatly increased by tillage, and that certain animals could be domesticated easily and made to serve man in life and after death. Having the breeding and feeding of these animals under his direct control, he has learned to modify them to suit his purpose. From a common stock he has evolved the draft, race and trotting horse, each with many variations. From the wild grains he has produced many varieties of each cereal, while at the same time he has increased the yield more than a hundredfold. By irrigation and cultivation he has converted thousands of acres of barren

desert into fields of golden grain, dotted with orchards bearing luscious fruits. When the territory now within our national continental boundaries was occupied by savage man, it supported only a few thousands, now under the stimulus of scientific agriculture it feeds, shelters, clothes, supplies the necessities of life to all and untold luxuries to many of its ninety millions of inhabitants and sends abroad enough to feed other millions.

In the long ago, some man observed the magnifying effect of a natural lens. The lapidary labored through centuries in the perfection and proper adjustment of lenses. The result was the evolution of the compound microscope. In 1849 a village doctor on the Rhine studied the blood of animals sick with anthrax under his crude microscope and compared it with the blood of healthy animals. He discovered the bacillus of this disease. This work under the genius and diligence of Davaine, Pasteur, Koch and others demonstrated the causal relationship between microorganisms and disease. The science of preventive medicine has been developed, the average of human life has been lengthened by fifteen years within one century and the way has been made clear for a like prolongation within a like period, provided the masses of the people acquire sufficient intelligence to properly utilize the facts already known. The capacity of the individual for work, rational pleasure and intellectual growth has been multiplied. Pestilential regions have been converted into fit dwelling places for man and his dominion over antagonistic conditions and forces of nature has been extended. Disease, which hitherto has excluded man from the fairest portions of the earth, has exacted heavy toll in all climes, has wrecked the greatest civilizations of ancient times and has more than once threatened the race with extinction, is now largely under man's control.

The foregoing are only illustrations of what science has done in the improvement of our race. I know of no scientific discovery which has not aided in the betterment of mankind and still science is in its infancy. Its ultimate goal is the domination of the forces of nature and their utilization in the betterment of mankind.

The fundamental principles and facts of the physical, chemical and biological sciences must be included in the courses taken by every student who wishes a broad, symmetrical education, whatever his business or professional calling is to be. Moreover, training in these sciences should not be of the amateur kind, but should be sound and thorough and accompanied by laboratory observation and demonstration. It should supply a sound basis which will enable the student in after life to reach correct conclusions, when scientific judgments must influence his behavior. The failure of those in high places to appreciate the value of scientific equipment and procedure has proved to be a serious matter many times. The importance of this subject justifies the mention of specific instances. When the Spanish-American War began in 1898, Congress refused to make appropriation for scientific medical equipment. The graduates of West Point up to that time had no instruction in army sanitation. Not a regiment, either regular or volunteer, went into the field with the medical equipment necessary to recognize either malaria or typhoid fever. Regimental commanders paid no heed at first to the protests of medical officers as to the location and sanitation of camps. The result was nearly twenty thousand cases of typhoid with more deaths from disease than from the shots of the enemy. Still, the only golden chapter in the history of that war is that which records the discovery of the manner of transmission of yellow fever, the lifting of the curse of this disease from the "Pearl of the Antilles" and the subsequent construction of the Panama Canal, made possible by this discovery.

The officials of the state of California denied the existence of the plague in San Francisco in face of the fact that its presence had been demonstrated scientifically. The result was the infection of certain rodents throughout a large territory and the expenditure of lives, money and energy in its eradication.

Duluth placed the outlet of its sewers and the intake of its water supply in close prox-

imity and paid for its ignorance in an epidemic of typhoid. A list of cities which have made similar mistakes is too long to give; a list of those which have followed scientific teaching would be shorter.

As I have indicated, our inability to utilize the known facts of preventive medicine means that the aggregate of human life in our population of one hundred million will measure one billion five hundred million less in years than it would were we, in the mass, more intelligent. This is a trustworthy and conservative statement of the stupendous price that this generation is paying for the ignorance of the many and for the special activities of Christian Science, the league for medical freedom and other impedimenta to the progress of scientific sanitation, which so far have been potent enough to block much needed legislation. There are many men directing our local, state and national affairs, among them graduates of our greatest universities and best colleges, who are as ignorant of, consequently as indifferent to, these matters which so seriously affect our national life—present and future—as are the untaught hordes that crowd into our country like so many cattle, through the gates of Ellis Island.

The fatalities due to ignorance of science make big figures in the mortality tables. Whether the infant lives or not depends most largely upon the scientific knowledge of the one who feeds it, and many a mother, who would give her life to save her child, murders it through ignorance. Surely, ignorance of such scientific knowledge as is necessary to protect health and life is a crime, a moral, if not a statutory one.

Descartes said that the purpose of all education is to enable one to reach sound judgment. Daily most of us are compelled to reach some judgment founded on scientific knowledge and training, and yet many college graduates are lacking not only in the knowledge but in the capability of comprehending it when presented.

I have indicated the subjects which in my opinion are essential to a liberal education, and I wish to add something about methods of study. It is a fallacy to suppose that every man who takes a college course gets an education and that all who do not have this privilege fail to be educated. The best university with the most complete equipment and the most learned faculty can do no more than supply opportunities. An education is not secured without effort on the part of the student. Too many college students follow lines of least resistance, dissipating instead of concentrating their energies, fall into bad habits, and instead of being improved are harmed by college residence. This is shown by their subsequent behavior. Forty years have I been in this university as student and teacher, long enough to see many uncouth, unpromising lads develop into eminent jurists, skilful engineers, able physicians and surgeons and, in short, honoring alike themselves and their alma mater in widely diversified spheres of activity by their deeds, but to-day I recall many who have been cast as useless driftwood upon the shores of life's sea. Were I asked to name the rocks which have caused the greater part of this wreckage I would mention—first of all, those that lie about the alluring islands of idleness. Inherited defects are not common among university students. The fact that they have been directed wisely at the start is proof of this, but it requires personal strength of character and fixedness of purpose to hold to the course. Next, but far less in number, are the high reefs of active dissipation. Lighthouses show their location and warn the sailor of danger, but he thinks he can pass through the narrows, where so many, less skilful than he, have been wrecked; he takes the risk and goes on to the rocks.

I drop the simile of the sailor and the rocks and continue my illustrations. One finds that he needs a knowledge of French or German in order to secure the fullest information. He elects the subject for one semester, works indifferently and fails. He concludes that he has no aptitude for language and tries something in another line in like spirit and with like result. Some men spend their lives in trying to find out what they are good for and die good for nothing. In my basic statements

I have emphasized the fact that effort is necessary in order to open pathways to the cerebral cortex and that *educatio strenua* is the only genuine article.

While I have made an earnest plea for a broad, liberal, fundamental education in order that we may be in intelligent touch with the basic conditions that control and modify human behavior, there is like physiological reason for advising every student to build on this broad foundation his specialty. When you have reared your house with heavy rocks for the foundation, massive walls, bound together with steel beams, on this you can carry up as high as you please the tower which will afford you an outlook. Take one subject and know everything that is known about it and if possible know more than any one else. In other words, in addition to your general knowledge be a specialist. To your general knowledge add the skill of the expert. The physiological reasons for this advice must be evident to all who have followed my line of argument. Neural pathways become smoother the more frequent the travel over them. I recommend expert development for the following reasons: (1) Extension of the domain of knowledge is secured. (2) The pleasure known only to the discoverer comes to him who does work of this kind. (3) It is a rest and recreation to turn into the well-worn paths along which thought moves automatically.

It is not essential that the special study, which I recommend, should be in the line of one's vocation. It may lie quite apart from business or professional duties.

The history of intellectual progress is quite in accord with the teaching that a broad educational foundation with the addition of expert learning gives the best results. I will mention a few illustrations of the educational training of men who have advanced human knowledge. William Herschell was a music teacher and never saw a telescope until he was thirty-five. His hobby was to grind lenses and make perfect mirrors. With these he discovered worlds, systems and universes. His great reflectors caught up light which left its source two million years ago. Our solar system became a mere speck in the range of his vision. Burnham became an enthusiast in the study of double stars, of which he discovered a thousand while he was still a stenographer in a Chicago court. Hutton, physician, chemist and farmer, showed that the earth's crust is a stone book, made up of pages, chapters and volumes. William Smith, the English surveyor, without college training, demonstrated that the characters used in this great stone book are the fossils. Cuvier, an anatomist, was the first to read some of the chapters in the history of the building of the earth. Buckland, doctor of divinity, extended the reading. Perraudin, the chamois hunter, suggested glacial action in shaping the earth's crust. The fox-hunter, Murchison, with Sedgwick, named the volumes of the stone book in order of their issue. Priestley, the dissenting clergyman, discovered oxygen. The Quaker physician, Thomas Young, the real discoverer of the undulatory theory of light, published many of his papers anonymously for fear that the rumor that he was a scientific investigator would injure his practise. Furthermore, he devoted some of his spare time to deciphering Egyptian hieroglyphics. Lavoiser, the father of chemistry, went to the guillotine. The official while signing his death warrant said: "The Republic has no need of savants." The honor of discovering the mechanical equivalent of heat and laying the foundation of the law of the conservation of energy is divided between the Manchester manufacturer, Joule, and the German village doctor, Mayer. The self-trained Quaker boy, John Dalton, became the founder of the atomic theory. Jefferson was the framer of the Declaration of Independence, president of the United States, founder of the University of Virginia and student of natural history. Franklin was printer, author, envoy from the young republic to France, postmaster general and scientist. The autocrat of the breakfast table was professor of anatomy in Harvard Medical School and his greatest contribution will not be found in his novels or poems, but in his article on the

"Etiology of Puerperal Fever," in which he divides honors with the great Hungarian obstetrician, Semelweiss. It is said of Goethe that he might have been the greatest scientist of his age had he not chosen to be the greatest poet. The man who made the greatest contribution to medicine in the nineteenth century, Pasteur, was not a physician, but a chemist. Elihu Burritt with his knowledge of many languages was a blacksmith. Virchow, the father of cellular pathology, was a socialistic-democrat, a member of the Reichstag and a vigorous opponent of Bismarck.

Permit me to briefly summarize my chief themes: Education is the modification of behavior through experience. The mechanism of learning consists of the nervous system with its sense receptors, conductors, centers and effectors. Education is secured by opening up neural pathways to the brain; this requires effort, but a frequently traveled path becomes smooth and easy. The course of learning does not show a constant ascent, but has occasional plateaus. Special pathways are needed for the acquisition of special knowledge. A fundamental education should include language, mathematics, history and science. No education can be symmetrical without training in all these. Upon these as foundation stones, the tower of special knowledge may be carried as high as the builder can.

Accuracy and promptness in formulating judgment are the ends sought in education; correctness first, and readiness next. When these qualifications are accompanied by the ability to be both prompt and effective in action the individual becomes of highest service to himself and his fellows.

I am aware of the fact that the advice of age does not meet a ready reception in the mind of youth. The old frequently envy youth its opportunities and wish that they were again young. This is idle and besides is not desirable. My generation has enjoyed great privileges. It has been my personal good fortune to know in the prime of life that great Englishman, the founder of antiseptic surgery, Joseph Lister, to sit at the feet of that great German, the discoverer of the tubercle bacillus, Robert Koch, and to look into the face of that greatest of Frenchmen, the man who laid the foundations of preventive medicine, Louis Pasteur. Were the price offered eternal youth, I would not tear from memory's book one page of its golden lessons, and I ask no higher immortality than that there should be found among my students those who have been inspired by my words and works, to carry forward the torch of science to light their fellow-men on their way to wider knowledge and its beneficent rewards.

Man has already accomplished much, but the greater tasks lie ahead. The productivity of the soil must be increased a hundredfold. Grains and fruits, yet unknown, must be grown. The heavy burdens that still oppress the shoulders of labor must be transferred to the tireless muscles of machinery. The literature of the higher civilization is, as yet, unwritten. Laws for which no precedents can be found must be framed and administered. The giant strength of intra-molecular energy must be harnessed into the service of man. A broader morality must govern our behavior, one to another, and a loftier religion must enthuse the common aspirations of the race. All this and much more must be achieved before man fully develops his highest potential greatness.

The world of effort is before you, young men and women. The road ad astra lies per aspera, but bruised heels and aching limbs count for naught when the way leads upward toward the mountain tops of human growth and perfection. Keep to this road, doing what you can to lift yourself and your fellows to a more rational life, and Michigan will have done well in bestowing upon you her richest gift, an education.

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THE USES FOR MATHEMATICS

MATHEMATICS has been termed the handmaiden of the sciences. Whether or not the mathematician himself accepts this as a truthful representation of his beloved science de-

pends upon what the word "handmaiden" connotes. If it is used to designate a supposed inferiority either in value or respect, or a menial and degrading compulsory service, he justly rebels against the use of this metaphor. If, on the other hand, divested of all suggestion of inferiority ordinarily concomitant with the use of the term servant, the word is only construed to mean a voluntary, honorable assistance, then, though deploring the use of a figure with such possibilities for false interpretation, he may not seriously object to its use. Mathematics undoubtedly does render incalculable aid to the exact and many other sciences.

Since mathematics antedates the other familiar sciences, astronomy excepted, its existence is surely not dependent upon their existence, nor can service to the other sciences be its sole aim and object. It does not live to serve, alone. It is not a born slave. It has an existence absolutely independent of any use to which it may be applied. The mathematician has pursued and will pursue his investigations regardless of material profit. The unselfish motive which directs his activities as well as those of other pure scientists is that love of knowledge pure and simple which seeks no reward other than the intellectual delight incident to the discovery of unknown truth, for him the revelation of hitherto unseen relations existent in the realms of number and space. However abstract and remote from practical application the truth revealed, matters not. He is not and refuses to be guided by mercenary motives.

If, however, in the light of popular conceptions, the standard of appreciation of science be the extent or importance of its application to the exigencies of daily life, mathematics gains rather than suffers from the lowering of the standard. Nevertheless the teacher of mathematics is frequently required by the prospective student to justify the usefulness of his courses. It occurred to me that a very definite and unprejudiced reply to such queries can be obtained from the Encyclopedia Britannica, 11th ed. This great work which is a "survey of the field of knowledge" presumably is impartial. Necessarily only the essentials can be given in such a work. We have selected from this book those subjects which have required the symbols of infinitesimal calculus in their treatment. The list is intended to be complete, but omissions are probable, owing to the haste in covering so many pages. Notice of omissions will be welcomed. Some of the subjects, such as infinitesimal calculus, are obviously mathematical, while the appearance of others, such as clock and sky, may surprise even mathematicians. The list would be far greater if we based it upon a lower subject such as trigonometry instead of calculus.

The list contains 104 headings which are as follows: Aberration, accumulator, æther, algebra, algebraic forms, amplitude, astronomy, atmospheric electricity, aurora polaris, ballistics, bearings, Bessel function, bridge, calculating machine, calorimetry, capillary action, chemical action, chemistry, clock, combinatorial analysis, condensation of gases, conduction electric, conduction of heat, curve, cycloid, differences calculus of, differential equation, diffraction of light, diffusion, dynamics, dynamometer, earth figure of the, elasticity, electrokinetics, electrolysis, electromagnetism, electrostatics, energetics, Fourier's series, function, fusion, geodesy, geometry, gravitation, groups theory of, gyroscope and gyrostat, harmonic analysis, heat, Herbart, hodograph, hydraulics, hydromechanics, illumination, induction coil, infinitesimal calculus, interference of light, interpolation, lens, light, lighting, logarithm, lubrication, magnetism, magnetism terrestrial, magneto optics, map, maxima and minima, mechanics, mensuration, meteorology, molecule, number, power transmission, probability, quaternions, radiation, radioactivity, series, shipbuilding, sky, solution, sound, spectroscopy, spherical harmonics, spiral, steam engine, stereoscope, stoichiometry, strength of materials, sun, surface, surveying, table mathematical, tacheometry, thermodynamics, thermoelectricity, thermometry, tide, time measurement of, transformer, trigonometry, units physical, vaporiza-

tion, variations calculus of, vector analysis, wave.

That mathematics is the handmaiden of the sciences is fully confirmed. Only about a fourth of the headings are those of pure mathematics. The wide variation of the subjects is evident. They cover the subjects of five sections of the American Association for the Advancement of Science.

If these facts are pointed out to the students, it will doubtless give them a greater interest in the subjects of mathematics, for even though they can not understand the references they can at least grasp their significance and approach their work with a conviction that it is worth while. It is hoped that this list may prove valuable to teachers in this way.

The student should appreciate early the importance of his mathematical training in his work, particularly in any subject of exact science. The haste made necessary by the limitations of time and the demand for more and more principles leaves little time for the application of known principles to explain nature in a mathematics class. The utility of the subject may thus not be as obvious to the inexperienced pupil as to the teacher. The subject of mathematics should not be considered by the pupil as mere continued drudgery without ultimate gain. When those uninspiring successions of hooks and crooks are clothed with a garb of meaning provided by nature herself and their real import and significance made manifest, they command a proper reverence because of that which they have accomplished. The beauty of the truth revealed or explained sheds a sense of beauty even over the cold abstract reasoning.

The student should know that that which he dimly foresees will appear before him as a panorama of extended beauty over which he can roam when once he has mastered that most wonderful and powerful instrument of modern analysis, discovered by Newton and Leibnitz, and so fully developed and applied by that constellation of immortal mathematicians the Bernouillis, Clairaut, Euler, Lagrange and Laplace, namely the infinitesimal calculus. He will then have a deeper insight into, and a partial comprehension of the plan of nature. Beauty concealed by ignorance of the mathematics necessary for interpretation will be revealed to him. He will then see that, of which the untutored mind has no conception because lying beyond its comprehension.

The massive bridge once wonderful because of its enormous size, when its principles of construction are understood becomes a thing of beauty, a wonderful monument to the intellect of the designer and constructor. The great tunnels, turbines, subways are changed to objects of wonder to those who are capable of understanding the difficulties overcome in their construction. The stars in the universe above which nightly dissipate some of their light upon the earth bespeak their Creator's glory in voices but faintly heard by those whose training does not enable them to comprehend the reign of law there prevailing. To such an one the heavens declare the glory of God in a more real and exalted sense. The earth is full of His glory. There will be "sermons in stones."

The extent to which natural laws have been discovered and expressed in mathematical equations must be a source of unending wonder. "Order is heaven's first law." The mathematical equation is the apotheosis of order. It will ever be a matter of self-congratulation to mankind that they can thus interpret natural phenomena by expressing the inexorable laws governing them in equations. We should better say that we are thankful to God for revealing to us those laws to which He has subjected His creation. It must compel a higher order of admiration for the Creator that He has made things thus.

One of nature's demands in which she is inexorable is a study of higher, the highest mathematics. The interpretation of her laws requires it. I close by quoting a scientist of wide fame. Sir John Herschel in the introduction to his celebrated "Outlines of Astronomy" writes:

> The utmost pretension of this work is to place its readers on the threshold of this particular wing of science, or rather on an eminence exterior to it,

whence they may obtain a general notion of its structure. . . . *Admission to its sanctuary and to the privileges and feelings of a votary is only to be gained by one means—sound and sufficient knowledge of mathematics, the great instrument of all exact inquiry, without which no man can ever make such advances in this or in any other of the higher departments of science as can entitle him to form an independent opinion on any subject of discussion within their range.*

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THE LATE WILLIAM SAUNDERS, C.M.G., LL.D.

In the death of Dr. William Saunders, C.M.G., late director of the Dominion Experimental Farms, which took place at London, Ontario, on September 13, there passed away a notable pioneer in the field of Canadian agricultural investigation, one who had worked hard and successfully in the best interests of his country for more than a quarter of a century and who, we rejoice to say, had lived to see in a large measure the fruits of his labor in a very material improvement of our basic industry, in methods, in crops and in stock throughout the length and breadth of the land. Comparing the agriculture of this country to-day with that of 1886, when Dr. Saunders entered upon what we may term his life work—the establishment of the Experimental Farm System—it is abundantly apparent that farming in all its branches has developed and prospered and we can not doubt that the varied activities of this system, in research and in the wide dissemination of information among our farmers, carried forward as they have been by Dr. Saunders and his co-workers with enthusiasm and skill, must have played a very important part in this agricultural progress. It has been a valuable and national work, and stands to-day as a monument to the initiative, the unflagging zeal and the untiring energy of Dr. Saunders, who held the directorship of the farms from their establishment to April, 1911, when he retired, owing to failing health and advancing years.

William Saunders was born in Devonshire, England, in 1836, and came at the age of 12 years to this country with his parents, who settled in London, Ontario. In early manhood he studied chemistry and pharmacy and subsequently established a business for the manufacture of pharmaceutical preparations, a business which he successfully carried on till 1886, when it was handed over to his eldest son, William E., who has remained since that date as head of the firm. In 1882, we find that his chemical knowledge had gained for him the post of public analyst for Western Ontario. Previous to that date he had taken a leading part in the founding of the Ontario College of Pharmacy, of which he was president for two years. He was also on the professoriate of the medical faculty of the Western University. His interest in entomology led him to assist in establishing the Entomological Society of Ontario, of which he was president for the period 1883–6. In the practical work of this society he maintained an active and warm interest throughout his life, acting as editor of its organ, the *Canadian Entomologist,* for thirteen years. As a result of his entomological studies, which were mainly of an economic character, he published in 1882 his work entitled "Insects Injurious to Fruit," a book that has been widely used as a text in agricultural colleges and by orchardists in the United States and Canada.

In 1868 Dr. Saunders purchased a small farm in the neighborhood of London and there, it may be said, he laid the foundation of his future work in horticulture, always his favorite study. This area of land, which he planted largely to fruit, enabled him to investigate and observe in the fields of experimental agriculture and horticulture, and no doubt furnished him with those qualities and that knowledge which led to his selection as the one best qualified to undertake the important task of establishing the Experimental Farm system. His many successes in the production of new fruits, flowers and grains during this period testify to his skill as an hybridist of the first rank.

Of his work as head of the Experimental Farms it will only be possible to give the

merest outline, but the annual reports and bulletins of that institution and his papers before learned societies give ample evidence of his active life in agricultural research. We can only refer here, and that briefly, to the results of his work with fruits and cereals.

In gooseberries he produced the Pearl and Red Jacket, both well and favorably known. With black currants he made many crosses and his Eclipse, Magnus Clipper, Climax, Success and Beauty have all established reputations. He crossed the red raspberry with the black cap, but the resulting varieties though of excellent quality and good bearers were not generally acceptable to the fruit trade by reason of their dark color. The "Sarah," however, has proved an excellent variety for home use, being valuable on account of its late fruiting. Early varieties of the red currant of Dr. Saunders's production are the Brighton and Count, both hardy, prolific and good yielders. In grapes, his Emerald, a white grape of fine quality, may be mentioned; it was held to be the best grape of the Canadian varieties exhibited at the Colonial Exhibition in London in 1886.

In ornamental plants he did excellent work, originating two fine and valuable roses, the Mary Arnott and the Agnes. Among the barberries also he left as a legacy several very interesting and highly ornamental hybrids.

His efforts and their results in hybridizing with apples are well known to the horticultural world. He set himself the difficult task of producing an apple that would be sufficiently hardy to withstand the rigor of the winter in our northwestern provinces. Many pages might be filled with an account of his labors in this direction. They were begun in 1894, using as the female parent the exceedingly hardy and exceedingly small wild Siberian crab, *Pyrus baccata,* and as the male parents a large number of hardy Russian and American apples. From these crosses he obtained his first fruit in 1899, and from among the bearing trees he found some that would justify their propagation. About 800 trees were set out and many of them have proved hardy and have fruited abundantly on the open prairie. Their fruit showed a very considerable increase in size, as compared with that of the mother parent, some of them having a diameter of one and three quarters inches. Among these first crosses stand out the Jewel, Sylvia, Prince, Tony, Elsa and Charles. Fruit of these has been produced at Fort Vermilion, in latitude 58°, where the winter temperature may fall as low as 60° below zero Fahrenheit.

From this initial work Dr. Saunders pushed forward, seeking apples of larger size and better quality. Taking the larger, he recrossed these hybrids with several hardy apples of well-known varieties and produced a number of still greater promise. Of these second crosses he planted about 400 trees, some of which have borne fruit two and a half inches in diameter and of good quality. These are now under test on the prairie farms and it is confidently expected that many of them will prove of value where apples can not at present be successfully grown.

In his work with cereals—a work which has proved of paramount importance and value to Canada—Dr. Saunders's endeavor was to produce an early ripening wheat of good quality, that might serve for districts in the Canadian northwest where the Red Fife, our standard variety, was in some seasons injured by early autumnal frosts. The story of this wheat breeding is a long and interesting one, covering many years of patient, skilful work. Many hundreds of hybrids have been produced and tested at the Central Farm. Hundreds have been discarded in the course of this investigation and hundreds were tried out for prolificness, earliness and bread-making qualities. Of this large number a few, perhaps a dozen, have been found worthy of introduction, and these, all crosses from the standard varieties, Red Fife and White Fife, are now well known and widely cultivated. Some mention must be made of the more important of these new wheats, which are all vigorous, productive and early in ripening. Preston and Huron are bearded, the equal of Red Fife in hardness and color. Stanley is a beardless wheat and in some respects from the commercial point of view perhaps somewhat infe-

rior to the foregoing varieties. Of somewhat different parentage is the next to be referred to and the best of them all—the Marquis—derived by crossing the Red Fife with the Hard Red Calcutta. Marquis, that practically from its first introduction, leaped into popularity and stands to-day as the equal of Red Fife in bread-making qualities and vastly superior to it as regards earliness in ripening. The selection of this splendid wheat, from a number of unfixed but closely related types, is the outcome of much painstaking and careful work on the part of Dr. Saunders's third son, Dr. Charles E. Saunders, who as Dominion Cerealist at Ottowa, took up this phase of his father's work in 1903. The Marquis has more than fulfilled the most sanguine expectations, and farmers and millers alike speak most enthusiastically of its many fine qualities and its extreme earliness. It has given excellent yields in Manitoba, Saskatchewan and Alberta, but not only is it a heavy cropper, but its grain is heavy and of excellent appearance, practically undistinguishable in all good qualities for milling and baking from Red Fife. It resists well adverse weather conditions. In earliness of ripening it is ready for harvesting from 5 to 10 days before Red Fife, a matter of no small importance for districts subject to early autumnal frosts. Such a combination of good qualities easily accounts for its success with farmers and its great popularity. It is rapidly replacing all the older early maturing wheats, including the Red Fife, on our western prairies. It won the prize of $1,000 given at the land exhibition in New York City in 1911, for the best 100 pounds of wheat grown on the continent of North America, and in 1912 was the successful competitor for the $2,500 prize awarded by the Dry Farming Congress held in that year at Lethbridge, Alberta. In 1913 it again received the highest award at the Congress held in Tulsa, Okla. We may thus safely say that the problem that Dr. Saunders set himself, to produce a good wheat with an early maturing habit suitable for general cultivation in the Canadian northwest, has been successfully solved. The production of the Marquis wheat has demonstrated the value of research work in agriculture and increased our possibilities as a wheat-growing country. Its value to Canada is scarcely to be calculated in thousands of dollars.

Dr. Saunders was a great lover of the beautiful in the out-of-doors, and to adorn the grounds he had charge of he introduced from other countries many shrubs and flowers. His planning and planting of the grounds and arboretum of the Central Farm and of much of the Government Driveway, at Ottawa, testify to his skill and good taste in landscape gardening.

Dr. Saunders's achievements were widely recognized. For his valuable work in promoting the interests of Canadian agriculture he was the recipient of many honors from learned societies and universities at home and abroad. He received the honorary degree of LL.D., from Queens University in 1896, and the University of Toronto bestowed on him the same honor in 1904. In 1905 he was created by His Majesty, the late King Edward VII., a Companion of the Most Distinguished Order of Saint Michael and Saint George. He was a Fellow of the American Association for the Advancement of Science, Fellow of the Linnean Society of London, Corresponding Member of the Royal Botanical Society, Fellow of the Chemical Society (London, Eng.), and held a membership in many other societies devoted to the natural sciences.

The *Transactions of the Royal Society of Canada,* of which Dr. Saunders was made a charter member on its formation in 1882, contains many contributions from his pen. The titles of some of these are "The Introduction and Dissemination of Noxious Insects," "The Importance of Economizing and Preserving Our Forests," "The Influence of Sex in the Hybridizing of Fruits," "Early Ripening Cereals," "Progress of Experiments in Cross-fertilizing at the Experimental Farms," "Results of Tree Planting on the Northwestern Plains," "Increased Production of Farm Crops by Early Sowing." These titles indicate his wide interests in economic phases of

agriculture. He was honored by election to the presidency of the Royal Society in 1906.

Dr. Saunders possessed a pleasing personality and was much beloved by those who knew him well. He was kind and considerate to all and ever ready to listen and help those who came to him for guidance and assistance. He was a good administrator, consistent, quiet and firm, with an excellent judgment of men and affairs, and these qualities no doubt contributed largely to his success as chief officer of the Experimental Farms. He never exaggerated to force home a truth, no matter how important it was, but contented himself in all his writings with a plain statement of the facts as observed and of the deductions that might safely be drawn therefrom. Anything of the spectacular or sensational, for the purpose of publicity or advertisement, were particularly abhorrent to him.

The name of Dr. Saunders is honorably and inseparably identified with the establishment and work of the Dominion Experimental Farms. To this end he labored long and earnestly and, as is well known, successfully. Canada gladly and gratefully acknowledges the benefits which those services have bestowed upon her agriculture.

FRANK T. SHUTT

THE MUSEUM OF VERTEBRATE ZOOLOGY OF THE UNIVERSITY OF CALIFORNIA

AMONG the research museums of America is one which in view of the brief period of its existence and the relatively small fund available for its maintenance has made such phenomenal growth and published such important results that it deserves the consideration and respect of all American naturalists. I refer to the Museum of Vertebrate Zoology of the University of California. This institution is only six years old, having been established in 1908 through the liberality and public spirit of Miss Annie M. Alexander. For years previously Miss Alexander had been engaged in amassing collections of West Coast mammals, and had conducted important expeditions reaching northward far into Alaska. There being at the time no museum on the Pacific coast with which she could cooperate in building up the splendid research collections she had in view, she sought and obtained the cooperation of the State University at Berkeley. During the first year a temporary building was erected, the cost of which was shared equally by the university and Miss Alexander.

Modern work in systematic zoology has demonstrated over and over again the futility of attempting critical studies of the relations and variations of species, or of the problems of their distribution, without the illuminating aid of large series of specimens from many localities. Keenly alive to this need, Miss Alexander, by her own efforts and those of her assistants in the field, has already brought together the largest collections ever made of West Coast terrestrial vertebrates—collections sure to be of inestimable and increasing value as time goes on. Her field explorations have extended from the deserts and mountains of southern California northward and westward to Prince William Sound in Alaska. Among the areas already worked in detail are the great interior valley of California, the Colorado Desert and other deserts and mountains of southern California, Owens Valley, the Mt. Whitney region, the Trinity Mountains in northern California, Humboldt Bay on the northwest coast, the Modoc and Goose Lake region of northeast California, certain mountains and deserts in northern Nevada, Vancouver Island and other parts of British Columbia, and the Sitkan and Prince William Sound regions in Alaska.

The magnitude of the collections—consisting mainly of birds, mammals, reptiles and batrachians—is surprising in view of the relatively brief period covered by the field work, the museum already containing more than 21,000 mammals, about 25,000 birds, more than 1,300 sets of birds' eggs, and upwards of 5,500 reptiles and batrachians.

Based on these rich collections, the university has issued a series of highly important faunal and systematic papers, illustrated by plates, text-figures and maps, some treating of the faunas of special areas, others of the species of particular groups. In nearly all cases

these contributions possess the merit and freshness of having been written by the men who actually did the field work on which they are based. The authors are Joseph Grinnell, the able and energetic director of the museum, and several assistants, past and present, namely, Harold C. Bryant, Joseph Dixon, Edmund Heller, Frank Stephens, Harry S. Swarth, Walter P. Taylor, and Miss Louise Kellogg.

The museum has adopted a most liberal policy in regard to the loaning of specimens, so that responsible naturalists engaged in revisions of groups may have the benefit of its material. In my own case, particularly in my studies of the big bears of Alaska, of which Miss Alexander has amassed the largest and most important collection in existence after that of the United States Biological Survey, I have enjoyed such unusual courtesies in the unrestricted use of specimens and field notes that I feel it a privilege as well as a duty to make this slight acknowledgment of the generosity and spirit of cooperation shown both by the founder and the director of the museum.

C. Hart Merriam

SCIENTIFIC NOTES AND NEWS

The American Society of Naturalists, in affiliation with the American Society of Zoologists, the Botanical Society of America, and the Society of American Bacteriologists, will hold its thirty-second meeting at Philadelphia, under the auspices of the University of Pennsylvania, on Thursday, December 31. The morning session will be open for papers on evolution, genetics and related subjects from members or invited guests. The program of the afternoon will be a joint symposium with Section F of the American Association for the Advancement of Science on "The Value of Zoology to Humanity." The annual dinner will be held in the evening of the same day.

The American Physiological Society, the American Society of Biological Chemists, the American Society for Pharmacology and Experimental Therapeutics, the American Society for Experimental Pathology and the Society of American Naturalists, will meet in the laboratories of the Washington University, St. Louis, on December 28, 29 and 30.

The New York Academy of Sciences and its affiliated societies had a general meeting at the American Museum of Natural History, on Monday, November 2, when Professor Reginald A. Daly, of Harvard University, gave a lecture on "Problems of Volcanic Action," which was followed by a reception.

Professor William Henry Bragg, who holds the chair of physics at the University of Leeds, is giving a course of four lectures on X-rays and crystals at Brown University, as part of the celebration of the hundred and fiftieth anniversary of its foundation.

Dr. Felix von Luschan, director of the Royal Museum of Ethnology in Berlin, and professor of anthropology in the University of Berlin, who was a guest at the Australian meeting of the British Association, is at present in this country, having been unable to return to Germany. He lectured last week at the University of Chicago.

Professor David Todd has returned to Amherst College, having made successful photographs of the corona of the recent solar eclipse from the estate of Count Bobrinsky, about a hundred miles southeast of Kieff. Owing to the mobilization, his instruments did not arrive in time, but he was able to obtain a camera and lenses that could be used.

Dr. Cyril G. Hopkins, head of the department of agronomy of the University of Illinois, has returned to his work after a year's leave of absence. Dr. Hopkins during the last year has been working for the interests of the south with the "Southern Settlement and Development Association," with headquarters at Baltimore.

President A. C. Humphreys, of the Stevens Institute of Technology, will act as president of the International Gas Congress, which meets in San Francisco next September.

The Alvarenga Prize for 1914 has been awarded by the College of Physicians of Philadelphia to Dr. Herman B. Sheffield for an essay entitled "The Fundamental Principles

involved in the Use of the Bone Graft in Surgery."

SIR ALMROTH WRIGHT has been appointed consulting physician to the British army in the field.

MR. HERBERT K. JOB, who for the past four years has been state ornithologist of Connecticut and lecturer on ornithology at the Connecticut Agricultural College, has resigned to take up work along similar lines for the National Association of Audubon Societies.

DR. GRACE L. MEIGS has been appointed by Miss Julia Lathrop, chief of the children's bureau of the U. S. Department of Labor, as expert on sanitation on the staff of that bureau. Dr. Meigs has recently been attending physician in children's diseases in Cook County Hospital, and will act in a general advisory capacity to the bureau in matters of child health and hygiene.

PROFESSOR W. K. HATT, of Purdue University, has been appointed by the county commissioners of Marion County, to report on the design of the West Washington Street bridge over White River at Indianapolis.

DR. M. A. ROSANOFF, professor of research chemistry in the Mellon Institute of Industrial Research, University of Pittsburgh, will give a series of about twenty-five lectures on the general subject "Equilibria in Heterogeneous Systems" beginning Tuesday evening, November 3, 1914.

PROFESSOR VERNON L. KELLOGG, of Stanford University, is giving in November a series of four lectures on "Heredity" before the Associated Charities of San Francisco.

PROFESSOR WILLIAM E. RITTER, of the department of zoology of the University of California and director of the Scripp's Institute for Biological Research, addressed on November 4 members of the zoological department, graduate students and faculty members at the University of Illinois on the work of the institute.

MR. G. R. MINES, fellow of Sidney Sussex College, Cambridge, and professor of physiology in McGill University, died on November 7, at the age of twenty-nine years. Professor Mines died while making experiments in his laboratory on the action of the heart, apparently as the result of some failure in the apparatus.

DR. HENRY GANNETT, geographer of the U. S. Geological Survey since 1882, president of the National Geographic Society, the author of contributions to typographical surveying, statistics and geography, died in Washington on November 5, aged sixty-eight years.

DR. FRIEDRICH VON GRANER, director of the Forestry Bureau in Stuttgart, has died at the age of sixty-eight years.

AT the meeting of the Association of American Universities, held at Princeton University last week, papers were presented by President George E. Vincent, of the University of Minnesota, on "The Granting of Honorary Degrees"; by Mr. George Parmly Day, treasurer of Yale University, on "The Function and Organization of University Presses," on "State Agencies of University Publication," prepared by Professor John C. Merriam, University of California, and presented by Dean Armin O. Leuschner, and on "Economy of Time in Education," by President A. Lawrence Lowell, of Harvard University.

THE seventh annual meeting of the American Institute of Chemical Engineers will be held in Philadelphia, Pa., from December 2 to 5. A program of excursions to a number of the large chemical manufacturing plants in and around Philadelphia is being arranged. A number of addresses and papers on "The Present Opportunities for American Chemical Industries" will be delivered by prominent chemical engineers and business men.

THE New England Geological Excursion, which was announced for October 16–17, was given up on account of rain.

GOVERNOR EBERHART, of Minnesota, has issued a proclamation setting aside the week of November 29 to December 5 for the study of general health problems.

IN accord with the unanimous vote of the first Pennsylvania Industrial Welfare and Efficiency Conference held in Harrisburg last year, John Price Jackson, commissioner of labor and industry, has issued a call for a sec-

ond conference to be held in the State Capitol at Harrisburg on November 17, 18 and 19, 1914. This conference is held under the auspices of the Pennsylvania Department of Labor and Industry and the Engineers' Society of Pennsylvania. The purpose of the conference is to enable the employers and employees to work out together the problems before them with reference to increasing the welfare of the employees and the prosperity of the industries. The conference last year was attended by approximately two thousand persons, many of whom were leaders in the labor and industrial world. The first session of the second conference will be called at 10 A.M. on November 17, and the meetings will close at 5 P.M. on November 19. The various sessions of the conference will be held in the State Capltol, Harrisburg. In connection with the conference proper, will be held a Safety, Welfare and Efficiency Exhibition which will open on the morning of November 16 and close on the evening of November 20.

We learn from the *Journal* of the American Medical Association that the Wesley Memorial Hospital of Chicago has established five fellowships to be given yearly to those graduates in medicine who have clinical scientific problems that they wish to solve. The work will be done under a joint board made up from the staff of the Wesley Hospital and the laboratory departments of the Northwestern University Medical School; the clinical work to be done in the hospital and the laboratory work in the laboratory of the medical school. The problems are restricted to those having direct application to clinical medicine and surgery or the specialties. The fellowships are open to any graduate in medicine. The recipient of the fellowship will be required to devote his entire time during the first year, at least, to the prosecution of his investigation.

Professor I. W. Bailey, of the Harvard Forest School, has returned to the Bussey Institution after an absence of several weeks spent in visiting a number of the middle western universities. The following papers, prepared in collaboration with Dr. E. W. Sinnott, were read by Professor Bailey:

University of Chicago, October 12: "The Effects of Decreasing Temperatures upon the Form and Structure of the Angiosperms."

Meeting of Central Botanists, St. Louis, October 17: "The Origin and Dispersal of Herbaceous Angiosperms."

Missouri Botanical Garden, October 21: "Some Problems in Phytogeography."

University of Wisconsin, October 26: "The Effects of certain Changes in Climate upon Arborescent Angiosperms."

University of Michigan, October 30: "Recent Educational Developments in Forestry and Lumbering."

A meeting of the New York Section of the American Electrochemical Society was held on November 10 in Rumford Hall to discuss "Contributions of Chemistry to Illuminating Engineering." The program was as follows: Milton C. Whitaker, Columbia University: "The Improved Incandescent Gas Mantle"; William C. Moore, National Carbon Co.: "Chemistry in the Development and Operating of Flaming Arc Lamps"; Ralph E. Meyers, Westinghouse Lamp Co.: "The New Tungsten Lamps"; R. D. Maily, Cooper Hewitt Electric Co.: "The Quartz Mercury Lamp"; D. McFarlan Moore, Edison Lamp Works: "The New Moore Tubes."

Pennsylvania so far exceeds all the rest of the states in the value of its mineral products as to stand almost alone. Exclusive of the value of pig iron, coke and other derived or secondary products not included in the total, the value of Pennsylvania's mineral production is nearly one fourth that of the entire country; and in 1913, according to figures of the United States Geological Survey computed in cooperation with the Pennsylvania Topographic and Geologic Survey Commission, it equaled the combined value of the production of West Virginia, Illinois, Ohio and California, the next four states in the value of their mineral product. Pennsylvania derives its mineral wealth almost entirely from nonmetalliferous mining operations. Except for a small amount of copper it produces none of the precious or semiprecious metals, and the only other metal which figures in the total production of

the state is iron, of which a small quantity (less than 500,000 tons of ore in 1913) is mined. In addition, however, to being the premier state in the production of coal, Pennsylvania leads also in the manufacture of cement, the burning of lime, and the production of mineral paints, sand, slate and stone. It is second in the value of clay products and natural gas, and sixth in the production of petroleum. Although not an iron-ore state, Pennsylvania is by far the leading producer of pig iron, which is obtained from the Lake Superior ores. The production in 1913 was 12,871,349 long tons, valued at $197,726,314. If the value of the pig iron made in Pennsylvania were added to the value of the other products of the state, the total values for 1913 would have exceeded $700,000,000, which is more than one fourth of the value of the total mineral production of the United States. The production of coal in Pennsylvania in 1912 amounted to 246,227,086 short tons, valued at $346,993,123; in 1913 the value was $388,220,933, an increase of $41,227,810, or 12 per cent., over 1912. Second in importance among Pennsylvania's mineral industries is the manufacture of Portland cement, closely followed by the clay-working industry. The production of cement in 1913 was 28,060,495 barrels, valued at $24,268,800, against 27,625,340 barrels, valued at $18,945,835, in 1912. The value of the clay products, exclusive of raw clay mined and sold, increased from $21,537,221 in 1912 to $24,231,482 in 1913. Although ranking second in the total value of its clay products, Pennsylvania is first in the production of brick and tile. A large part of the fire clay is mined in connection with coal mining and becomes in reality a by-product of that industry.

UNIVERSITY AND EDUCATIONAL NEWS

MR. W. K. VANDERBILT has given $135,750 toward the purchase by Columbia University of a half block of land on 117th Street adjoining other land owned by the university.

THE University of Pennsylvania receives $50,000 by the will of Miss Anna Blanchard of Philadelphia.

THE late Dr. Morris Longstreth, who at one time held the chair of pathological anatomy in Jefferson Medical College and later was in practise at Cambridge, Mass., and Barcelona, Spain, made the College of Physicians of Philadelphia his residuary legatee.

THE annual dinner of the faculty and managers of Haverford will be held on November 23, when questions relative to the curriculum and the general policy of the college will be discussed.

DR. WILLIAM WADDELL BOYD was inaugurated president of the Western College for Women, Oxford, Ohio, on November 4. His inaugural address was entitled "The Intelligent Use of the Intellect."

A CABLEGRAM to the N. Y. *Sun* states that M. Henri Bergson, presiding at a meeting of the Academy of Moral and Political Sciences on November 7, announced that Arthur Raffalovitch, Russian privy councillor and attaché of the Russian Embassy in Paris, a correspondent of the academy, has given his library, which he has been collecting for thirty years, to the University of Louvain. M. Bergson added that a committee is being formed to reconstitute the library's funds. It is known that the Germans removed the most precious manuscripts before burning the library, so it is hoped that the treasures eventually will be restored to Louvain.

THE Medico-Chirurgical College of Philadelphia has, according to the *Journal* of the American Medical Association, made the following faculty changes: Dr. Herbert H. Cushing, professor of practical anatomy; Dr. Ardrey W. Downs, professor of experimental physiology; Vernon K. Suydam, professor of physics; Charles E. Vanderkleed, professor of analytical chemistry; Dr. John H. Small, associate professor of bacteriology; Dr. Eugene A. Case, associate professor of pathology; Dr. Philipp Fischelis, associate professor of histology and embryology; Dr. Guy Hinsdale, Hot Springs, Va., associate professor of climatology; Dr. Arthur C. Morgan, associate professor of medicine, and Dr. John Stewart Rodman and Dr. John J. Gilbride, associate professors of surgery.

Dr. Johannes Meisenheimer, associate professor at Jena, has been elected professor of zoology at Leipzig, to succeed the late Professor Chun.

Dr. Paul Koebe, associate professor at Leipzig, has been elected professor of mathematics at Jena, as successor of Professor Johannes Thomae.

DISCUSSION AND CORRESPONDENCE

SUNFLOWER PROBLEMS

Professor Bateson, in his British Association address (Science, Aug. 28, 1914, p. 300), has raised the question whether the red sunflower may not owe its chestnut color to the loss of an inhibitor, instead of the positive addition of a factor for red. Are all yellow-rayed sunflowers potentially red, but prevented from becoming so by something which "stops down" the series of chemical processes which would produce redness?

So far as I can determine, the cultivated *Helianthus annuus* is derived from the wild *H. lenticularis,* which has a dark disc and orange rays. The disc florets of this plant have small triangular lobes, which are a sort of dull wine red owing to an abundance of anthocyan pigment. The rays are orange, without red. The disc bracts have dark red ends. There is evident anthocyan pigment in the stem, producing a mottled effect. Thus, it is clear that the *kind* of pigment which characterizes the red sunflower is rather abundantly present in the wild plant, although it does not invade the rays. Occasionally, however, the rays show a little red. At Longmont, Colorado, August 30, 1914, I found a plant of *H. lenticularis* having the middle third of the rays beneath with the apical half variably light brownish-red. Microscopic examination showed cells with anthocyan, which became redder with acid. On the upper side, the rays were entirely orange as usual. In the red sunflowers, it is this middle tract of the under side of the rays which is generally especially heavily pigmented. Had this Longmont plant a special "factor for red," or had some of the effects of the normal reddening factor of the disc florets spilled over, as it were, on to the rays? In our red sunflowers, we find that the heterozygous forms may be very richly colored. Nevertheless, they may be almost wholly yellow-rayed. The most extreme case of this sort is a plant grown this year, which has very purple stems and branches, but the very rich orange rays apparently wholly without red, though a lens shows a little scattered red. In this case it would seem natural to think of the red being inhibited. However, the appearance of yellow-rayed heads at the end of the season on heterozygous more or less red-rayed plants suggests not so much the late development of a special inhibitor, as the failure under adverse conditions of the color-producing mechanism. In other words the "inhibitor" here is nothing more than the withdrawal of the needful stimulus.

The monocephalous garden sunflowers have the disc yellow, the red having disappeared from the disc florets. The same variation occurs from time to time in the related wild species (*e. g.,* the variety *phenax* of *H. petiolaris*). Dark disc is strictly dominant or epistatic to yellow. Here we naturally speak of the loss of a factor; but carrying the inhibitor postulate a little farther, we can assume that we have here a second inhibitor, acting upon the disc, only operating when the plant is homozygous for it. A supposition of this sort is certainly fatiguing to the imagination.

In homozygous red-rayed sunflowers, the pigmentation may be intense.[1] We not only have the form (var. *ruberrimus,* nov.) with the rays deep chestnut red all over; but this year we obtained one (var. *niger,* nov.) with the rays practically black above, slightly red apically, though beneath they showed on one side a streak of orange. (The orange streak on one side, not always the same side, beneath, is a regular character of the very red varieties. I am not at present able to explain this asymmetry, unless it has to do with the manner

[1] It is singular that the pigmentation of the seed (fruit) follows quite different lines. Sutton's tall primrose variety of *H. annuus* has long black seeds, and in a cross with brown-seeded varieties, the seeds of F_1 come broad and dark brown.

of folding in the bud, whereby one side is deprived of light.)

In the vinous series (red on primrose) we have corresponding forms, one (var. *vinosissimus,* nov.) having the rays entirely dark wine red.

On the whole, and in view of the fact that there are no wild species of sunflowers with red rays, it seems reasonably certain that the red represents a "positive" variation; but, as with color variations in animals, there may well be also a diluting or inhibiting factor, which when present sensibly modifies the expression of the factor for red. It is not necessary, however, to suppose even this, since various degrees of stimulation might equally bring about the results. Miss Wheldale, describing analogous cases in chemical terms, suggests that if the local oxidizing capacity of any tissue is greater than its reducing power, this is indicated by the local appearance of anthocyanin; if the reducing power is greater than the oxidizing power, no pigment results. Thus, she says, the *loss* of a dioxidizing factor would produce color, as may be the case in the red-leafed beech.

Duggar found that in the tomato a red pigment (lycopin) and a yellow (carotin) both occur. In yellow varieties only the carotin occurs; but in genetically red varieties a high temperature precludes the formation of lycopin, and yellow fruits result. In the case of the red sunflowers, the red color very commonly fades more or less after the flowers open, probably in part owing to growth without corresponding increase of pigment, which thus becomes diluted. Dr. J. R. Schramm of the Missouri Botanical Garden informs me that in the hot summer of St. Louis this fading is excessive, good red forms becoming practically yellow before they are over. Also, on comparing notes with Mr. D. M. Andrews of Boulder, Dr. Schramm observed that roses with pale tints are much less colored at St. Louis than in Colorado.

With regard to a possible "dilution" factor, it is to be noted that in the series of yellow and orange pigments, which occur in visible particles, dilution can be seen, as explained in SCIENCE, August 21, 1914, p. 284. More recently we have obtained the fourth possible combination of this series, dilute orange, in plants of the *bicolor-vinosus* type.

In the paper just quoted, irregularities in the distribution of anthocyan pigments were described. I have now to record a similar peculiarity in which the solid pigments are involved. An F_2 plant from very pale *Helianthus cucumerifolius* $\times$ *H. annuus coronatus* had broad orange rays, with about the basal half strongly washed with chestnut. A single ray, however, was primrose color, slightly streaked with vinous. This ray had an orange longitudinal stripe on the under side. The difference here is only in the yellow, the difference in the red (chestnut and vinous) being entirely due to the character of the background.

A few words may be added regarding gigantism. In 1913, and again in 1914, there appeared among our red sunflowers a certain number of gigantic plants, fully ten feet high, nearly always with yellow rays. These numbered perhaps about 25 per thousand plants. The occurrence of these plants this year has been especially striking, in a large group of very good reds. One occurred, blooming very late, in the series of F_2 plants from *primulinus* $\times$ *coronatus,* which gave us our first vinous. Have we here a sort of jack-in-the-box effect, some inhibitor of growth being lacking in a certain number of cases? The *coronatus* we used had some "Russian" (var. *macrocarpus* D.C.) in its ancestry, which might bring a recessive tendency to gigantism. These large plants, however, were much branched and had dark discs.

T. D. A. COCKERELL
UNIVERSITY OF COLORADO

X-RAY DIFFRACTION PATTERNS

THE diffraction patterns discovered by Friederich, Knipping and Laue have been shown to be due to the arrangement of the atoms of crystals into planes. These patterns are used to indicate the spatial distribution of atoms in crystals.

An experiment illustrating these patterns can be very easily shown to an audience by permit-

ting a beam of light to enter a dark room and fall upon the face of a diamond such as used in rings. The diamond is held a few inches from the hole through which the beam of light enters and upon this screen is thrown a large number of bright spots very closely resembling the X-ray patterns. By moving the diamond to and fro from the screen or by rotating it the form of the pattern can be altered. The portions of rays that enter the diamond and are reflected from the rear surfaces may show the spectral colors.

This experiment can be demonstrated to a class very easily and should be of some use in explaining crystalline structure.

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A NEW METHOD OF PREPARING SPIDERS FOR EXHIBITION IN MUSEUM GROUPS

The preservation of spiders for museum purposes has always presented serious difficulties on account of the fact that the abdomens of the Arachnids lose their shape and color on drying. The usual method of preservation in liquids is of course out of the question when spiders are to be used as part of a faunal group. By preparing an artificial abdomen of wood and fastening it to the cephalothorax of the actual specimen I have found it possible to produce an imitation which can scarcely be distinguished from the living animal.

A large number of specimens of the desired species must be collected, to allow for the selection of full-grown animals. It is advisable to keep them alive for several days and to supply them with plenty of food; as it often happens that either conditions of the weather do not allow an ample food supply or else the insect may be abnormal on account of a recent or impending molt. In such instances the abdomen may often be not quite half the size of that of a well-fed specimen or one filled with eggs.

After the insect body is fully developed, the imitation abdomen must be made before killing. For this purpose a piece of light soft wood is used, carved in the exact form and size. Then the coloration is put on in precise shade and pattern.

Next the spider is killed. The best way to kill it is by putting it in a corked bottle containing cyanide. According to the strength of the cyanide and the size of the spider this takes from one to two hours. If the length of time is not sufficient the spider may later recover. After being sure that the spider is dead an insect pin is driven through the center of the cephalothorax and the insect fastened into a cork sheet, the legs being put in position and supported with pins. After being prepared in this manner, the insect must be kept in a warm and dry place, protected from dust.

After a few days, when the insect is thoroughly dry, the shrunken abdomen may be carefully removed and replaced by the wooden model.

Ignaz Matausch
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SCIENTIFIC BOOKS

Igneous Rocks and Their Origin. By Reginald Aldworth Daly, Sturgis-Hooper Professor of Geology, Harvard University. New York and London, McGraw-Hill Book Company, Inc., 1914.

In a previous publication Professor Daly expressed the opinion that "to be more productive geology should be more speculative." In this sense the author has become highly productive. In the introduction to his book on "Igneous Rocks and Their Origin," which is an elaboration of his previous publications, he qualifies the estimate commonly put on the value of experimental research in physics and chemistry by remarking that, while the mathematical methods employed are precise the premises relied on are not. How much lower value then must be placed on the results of a procedure in which both the premises and the mode of reasoning are seriously at fault!

The author pays a just tribute to the effectiveness of a regulated imagination, but fails to warn the student of the havoc which may be wrought by a badly regulated one, which like a defective aeroplane may bring destruction not

only to the aviator but to those who may be under him; a simile suggested by his observation that geology is "a science involving long excursions into space." It is to be hoped that in his contributions to higher education Professor Daly will keep this risk constantly before his readers.

His statement that "science is built on a long succession of mistakes" is inexact. Very serious mistakes have been made in the past, and obviously are being made still by those who are earnestly endeavoring to build it up, but it is to be hoped that very little of the structure of modern science is built upon mistakes. It is true as the author says that "their recognition means progress." Most surely, perhaps, when we recognize our own, for "thus we rise on stepping stones of our dead selves to higher things."

The author seems to be outside of petrographical conceptions when he imagines that "science is drowning in facts." The solid facts of petrology should furnish the best building material for a scientific structure, as well as for a foundation, and are not in such a flux as his metaphor suggests. There are many evidences in the book before us that its author confuses facts and subjective conceptions or hypotheses about them; indeed, he closes the introduction with the statement that "The 'facts' of to-day are the hypotheses of yesterday," and he demonstrates his confidence in this assertion by citing as facts in one chapter what were his own hypotheses in a previous one.

In his zealous endeavor to advance the science of petrology Professor Daly has the earnest sympathy of his fellow workers, however much some of them may disagree with him as to his methods of thought and of presentation, or as to his assumptions and conclusions, but the present writer is somewhat at a loss as to how one should interpret Professor Daly's statement that "the best sympathy is expressed in constructive criticism." If this means that the construction should be an elaboration of his hypotheses and theories, then the reviewer regrets that his sympathy is not of that kind. However, if constructive criticism consists in the presentation of other hypotheses, built with the aid of the imagination on other premises, which seem to the writer to be more secure and more in accord with modern conceptions regarding the physics of the earth and the essential characteristics of igneous rocks and their molten magmas, then he would present Professor Daly with the views expressed in the writer's recent lectures on volcanism at Yale University as a token of his sympathy, and would ask him to look upon the present criticism of his work on "Igneous Rocks and Their Origin" as an evidence of the serious concern which the writer feels for the science which both of us are striving to promote, and of his sense of duty in pointing out what seem to the writer some of the mistakes of method employed with such dangerous effectiveness by the brilliant but, as it seems to the writer, mistaken author of the volume in hand.

Since the book is an elaboration of papers already published by the author, which are familiar to most students of petrology, it will not be necessary to state at length the contents of the work which are given in a brief abstract in the first chapter, from which may be gotten more definite ideas of the author's views than are obtainable in some instances from the involved discussions in subsequent chapters. Moreover, the book is so full of statements, citations and tabulated material, much of which is open to criticism and debate, that it would require an exhaustive treatise to discuss the whole work thoroughly. The volume represents a great amount of energy and thought expended through years of study and speculation, evidences of which may be found in extensive tables compiled to illustrate the author's hypotheses, as well as in abundant bibliographic references which must represent but a small part of the author's researches into the literature of petrology, a large part of which would seem to be of little value for his purpose.

It seems to the writer that the most fundamental feature of the book is the mistaken method employed by its author in his attempts to solve the problems of volcanism,

which involve the character and origin of igneous rocks and their antecedent magmas, a method which is disclosed by the construction of the book, as well as by the statements of the author regarding it. The work is divided into three parts. The first broadly treats of what the author considers the facts which need explanation in a philosophy of igneous rocks. The second contains a general, "eclectic" theory of the subject. The third outlines the results of applying this theory to the so-called "facts" previously mentioned.

By way of introducing the "facts" in the case the author devotes a chapter to the Classification of Igneous Rocks, and thereby reveals his lack of acquaintance with some of the fundamental principles of modern petrology, those based on the physical chemistry of crystallizing solutions so far as known. The chapter also demonstrates the inexactness, or incoherence, of his logic, or his indifference to the meaning of words, for on page 2 he says that "Reasons are stated for preferring a classification founded on actual mineral composition," and on page 9 it is shown that it is not possible to determine the actual mineral composition of igneous rocks, and that recourse must be had to chemical analyses. He then proceeds on the assumption that a collection of rock analyses grouped by Rosenbusch according to Rosenbusch's system of mineralogical classification is a classification according to the mode of a rock, the mode having been defined as the actual mineral composition of a rock expressed quantitatively. Rosenbusch himself states that his classification is based on the most noticeable minerals, in porphyritic rocks, with little or no regard in some instances to the minute minerals in the groundmass, which may form a large part of the rock. The author's misuse of the term mode as well as his statements regarding the Quantitative System of Classification, which he calls the Norm System, show plainly his failure to comprehend the fundamental principles both of this system of classification and of the chemico-mineralogical relations in igneous rocks on which the system was founded. This is further shown by his effort to indicate its methods by a hypothetical jumble of biological species.

The author pays a high tribute to the leadership of Rosenbusch in connection with rock classification, whose system he professes to adopt, with modifications of his own, but he violates absolutely the essentials of the system in the third part of his book, and he ignores Rosenbusch's judgment on principles which conflict with the main thesis of his "eclectic" theory. Rosenbusch based his system on the microscopical petrography of igneous rocks, in which branch of petrology he was the acknowledged leader, and it was not to be expected that in the later years of his brilliant career he would have undertaken to reconstruct his system of classification in the light of new discoveries in allied branches of science. But it must not be supposed that he had no appreciation of the march of events; toward new or revolutionary ideas he held a conservative course, and upon one occasion in a discussion of new ideas with which he was in sympathy he remarked to the present writer that he must not introduce such changes into his book suddenly, but gradually in successive editions, for otherwise his readers would not follow him. On the same occasion he volunteered the remark: "I do not know what the future petrography will be, but it will be quite different from what it is now," in 1890. It was as though this great leader of a wandering people had had a vision of a land into which he himself was not permitted to enter.

For the rocks grouped together by Rosenbusch Professor Daly calculates average analyses, chiefly from the tables of analyses published by Osann, and assumes that these averages represent types of each group, the subjective character of such calculations not being considered by him as objectionable. A fundamental error in his procedure with respect to igneous rocks appears in the misstatement, copied from Rosenbusch, that coarse-grained intrustive rocks differ from their corresponding porphyry and lava forms by the relative proportions of their chemical constituents.

This error vitiates some of the fundamental hypotheses developed in subsequent parts of the book (p. 229). It has been clearly demonstrated that these supposed differences rest on the failure of the qualitative system of Rosenbusch to classify rocks by their actual mineral compositions, or modes, and also upon the fact that the modes of chemically similar magmas may differ because of the different physical conditions which may have controlled the chemical equilibria within solidifying magmas. This well-known principle is lost sight of by Professor Daly. Apparently the author's units for classification have been petrographical names and definitions, and not the rocks themselves, with which he seems to be less familiar.

Having qualified the Qualitative System of Rosenbusch to suit his conceptions of it, the author proceeds in the third chapter to employ it quantitatively, and undertakes to determine the relative abundance of various groups of names which he has called "clans," assuming that the areal distribution of igneous rocks, as represented on maps made at various times by many geologists and petrographers, will furnish a reliable basis for the comparison of actual rock bodies and of the relative amounts of various kinds of igneous rocks! To one familiar with the methods of geological cartography, with methods of observation and petrographical determination of large areas of igneous rocks, and also with the modes of occurrence of rocks in the field, the idea of employing the areal representations of such bodies as a means of estimating the relative quantities of rocks grouped by Professor Daly into "clans" is remarkable both as an evidence of the author's respect for the data before him and as an indication of his conception of the structural geology involved. Great areas of igneous rocks are commonly so complex that their mapping is not attempted in detail on many maps, and in some regions a thin surface flow of lava may overlie hundreds of square miles of other igneous rocks, which is the case in eastern Idaho, for example, where basalt overlies rhyolites which are not represented on maps of the region. The value of his efforts to determine the relative quantities of various kinds of igneous rocks, as well as of the classification he has applied to the rock bodies studied, appears in his conclusion that the rocks of the globe belong quantitatively to two types, "granite" and "basalt"; a statement which shows that his petrography goes back to that early period when "granites" and "greenstones" were considered to be the chief groups.

In shutting his eyes to the great volumes of intermediate rocks which form the chief bulk of igneous magmas Professor Daly exhibits the results of the method which controls his researches, and also to what extent an observer may "feel the pressure of the category" (p. 62). It goes without saying that the writer disagrees with Professor Daly as to the value of the observer under such circumstances. The lack of breadth in his discussions of some subjects is shown by his failure to give proper weight to the effects of erosion in revealing the deeper-seated intrusions of older times, as well as in removing older surface lavas, which accounts for the apparent differences he finds in the modes of eruption of magmas in different geological periods.

The chapters on intrusive and extrusive rock bodies are full of excellent diagrams and illustrations of many instances which have been taken from many sources, as the author states, and they contain a great deal of valuable material. However, with his opinions regarding batholiths the writer takes many exceptions which have been expressed in the lectures on volcanism already referred to. It is to be regretted that in his discussion of these bodies Professor Daly is constantly confounding observed facts with hypotheses to the serious confusion of the reader. His suggestion as to the origin of the rhyolite plateaux of the Yellowstone National Park, which is expressed diagrammatically in Fig. 71, shows the limits to which he is willing to be led by his speculations, and becomes a *reductio ad absurdum* for his batholithic hypothesis, of which he says it is a logical outcome, when one considers the geological structure of the region and the character of the rhyolite lava flows

forming the plateaux. The diagram referred to would seem to be a limiting case of the author's indifference to rational geodynamics, yet in the introduction to Part II. he states that "Throughout the preceding chapters the attempt has been made to admit only such descriptions and classifications as are direct expressions of objective facts."

The second part of the book begins with a discussion of the possible temperature and constitution of the earth, which he concludes consists superficially of an outer "acid" or "granitic" shell with a partial covering of stratified rocks, underlaid by a liquid "basaltic" shell. He states that the phenomena of intrusion and of rock variation can all be explained by the interaction of these shells, to demonstrate which the succeeding chapters were written. The hypothesis of concentric zones of granitic and basaltic magmas is like those of von Waltershausen, Durocher and others, and the synthetic features are similar to those of von Cotta. These hypotheses were evolved before the closer study of igneous rocks had shown the error of their fundamental conceptions. This modern knowledge Professor Daly ignores, and any attempt to convince him of his mistake would involve a course of instruction which he does not appear to desire. It is not too much to say that the statements he makes in support of his hypotheses regarding the constitution of the lithosphere, the processes of magmatic intrusion, of overhead stoping, assimilation and subsequent differentiation appear to the writer to be in part fundamentally wrong and in many cases thoroughly misleading to the reader. It would be an extensive undertaking to criticize his elaborate and voluminous arguments in detail, and it would be a task the writer does not care to attempt.

His discussion of "abyssal injection" which is based on the assumption that the earth consists of a "relatively thin crust overlying a fluid basaltic substratum of unknown thickness" (p. 192), and the diagrams illustrating his conception of the process, as well as of that of batholithic intrusion, and also the scheme of rock genesis which is given in Part III., are all based on the principle of contrasting two assumed antithetical qualities, or groups of properties, such as a "solid crust" and a "liquid substratum," an "acid" rock mass and a "basic" rock magma; corresponding to the two magma hypothesis of Bunsen with its synthetic corollaries. It is a system which does not appear to be in harmony with modern notions of evolution, but finds its counterpart in metaphysics, with its antithetical right and wrong. It seems to the writer that physics, not metaphysics, should furnish the basis for modern petrology.

In calling his speculations an "Eclectic" theory Professor Daly has not distinguished it from any other complex theory of the present day, which in the nature of science must be derived from many other theories or hypotheses, previously enunciated. All modern complex theories are eclectic, or are but slight modifications of previous ones. The theory to which that of Professor Daly is most closely related, as he points out, is that of Loewinson-Lessing, published fifteen years ago, which its author called a "synthetic-liquation theory of differentiation," a name which has the merit of being descriptive.

The third part of the book before us outlines the result of applying the author's theory to the problem of petrogenesis. The result is a most remarkable distortion of petrographic relationships, and a thoroughly artificial scheme. The grotesqueness of the conclusions might be relied on to condemn the process of reasoning by which they have been attained were it not for the eminence of the author, the magnetism of his personality, and the effectiveness of his address, which give a seriousness and force to his writings that will carry conviction to many readers who have no means of independent judgment, both as to the correctness of his direct statements in each case and as to which are realities and which subjective conceptions.

With Professor Daly's tireless energy and vigorous methods of attack; with the acknowledged honesty of his conviction as to the correctness of his reasoning, but with his lack of discrimination between the relative values of objective realities and subjective conceptions;

with his chivalrous devotion to a "complete mental system," and with his courage in the use of his speculative imagination—he is a veritable knight errant in petrology.

J. P. IDDINGS

BATAVIA, JAVA,
August 3, 1914

Bacteria in Relation to Plant Diseases. By ERWIN F. SMITH, in charge of Laboratory of Plant Pathology, Bureau of Plant Industry, U. S. Department of Agriculture. Volume three. Vascular Diseases (Continued). Washington, D. C. Published by the Carnegie Institution of Washington, 1914. Quarto, viii + 309 pp.

It is not so many years since we were assured by some foreign bacteriologists that bacteria did not and could not produce diseases of plants. Less than a dozen years ago the writer of this review took part in an impromptu discussion in the bacteriological laboratory of one of the German universities in which it was vehemently contended on the one side that American bacteriologists showed their incompetence by thinking that the bacteria they found in plants had any pathological significance. Even pear blight was held to be due to some other than bacterial action. The sweeping assertion was made that no plant diseases whatever were due to the presence of bacteria.

The three stately volumes which Dr. Smith has already issued remind one of these recent opinions, and one wonders what can now be said by these same disbelievers in the pathogenic relation of bacteria to the diseases of plants. At any rate, Dr. Smith has here marshaled an array of facts that must be staggering to one who still feels that bacteria do not cause plant diseases.

The present volume deals about equally with diseases of monocotyledons and dicotyledons, principally with diseases of sugar-cane and maize, and with those of potato, tomato and tobacco. A full account is given of Stewart's disease of sweet corn and all the evidence going to show that it is disseminated on the seed. The morphology and cultural characters of *Bacterium solanacearum* which produces the "Brown Rot" of potatoes and other related plants are given in full. The destructive tomato disease, due to *Aplanobacter michiganense,* is also illustrated and distinguished from that due to *Bacterium solanacearum.* Growers of tobacco will find a separate chapter on the bacterial wilts of tobacco.

Throughout the book are found more than 150 text illustrations, and 47 full-page plates, some of the latter colored. The reader will share the author's satisfaction with the way that the printer has been able by the use of excellent paper and ink, and carefully selected type, to bring out the text and the illustrations. In passing it should be noted that only twenty-nine of the illustrations are borrowed from other authors, so that in this regard also this book is a contribution to the literature of plant pathology.

Although this volume was issued in the early part of August, 1914, it is known that the manuscript left the author's hands about two years earlier. During its slow progress through the printer's hands Dr. Smith has added many a paragraph and illustration, so that in fact the volume has been brought down as close as possible to its date of issue.

We need only pause a moment to call attention to the admirable index, which is all that an index should be. It is first of all an alphabetical index of the topics treated and the terms used, but, in addition, these are so systematically arranged that the index is a conspectus of the whole volume, and especially of its various sections.

As the writer of this review runs over this volume and its predecessors he is still more impressed with the feeling that some of these days the botanists of this country must ask very emphatically for a text-book on plant diseases prepared by Dr. Smith. A text-book from his hand could do much to place plant pathology on a truly scientific basis.

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The Bacteriological Examination of Food and Water. By W. G. SAVAGE. Cambridge, England, University Press.

Dr. Savage has prepared this volume of 170 pages as "a practical manual" dealing with the bacteriology of water, milk and other food products and air. It begins with two introductory chapters dealing in particular with the significance of colon bacilli, streptococci and anaerobic spore formers as "indicator organisms." Then follow chapters on Water, Soil and Sewage, Shellfish, Milk, Modified Milk and Milk Products, Bacteriology of Meat and Meat Products, Air and the Determination of Antiseptic and Germicidal Power.

A book of this size covering so wide a field can not from the nature of the case give a complete and authoritative treatment of the various subjects under discussion—such a treatment for example, as Dr. Savage has given to the problems of water bacteriology in his excellent "Bacteriological Examination of Water." On the other hand the discussion seems somewhat too discursive and the procedures and standards of interpretation are stated with insufficient clearness and definiteness to make the book altogether satisfactory as a student's text-book or a practical manual for the laboratory worker. Dr. Savage does, however, give an excellent summary of recent English discussions in regard to the subjects treated, with a good list of reference to original sources which will make the book valuable for advanced students.

From an American standpoint the most serious defect in this work is the almost complete lack of acquaintance with the progress which has been made along these lines on this side of the water. It seems strange, indeed, to find a book on the bacteriology of milk, water, air and food with no reference to American investigations on the direct microscopic examination of milk, on the lactose bile presumptive test, on the bacteriology of sewer air and on the bacteriological examination of shellfish.

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Molecular Physics. By James Arnold Crowther. Philadelphia, P. Blakiston's Son & Co.

This little book of 175 pages, though entitled "Molecular Physics," contains in reality only such material as is usually found classified under the general head "Electronics." It represents an attempt to present in elementary, almost in popular, form the recent developments in physics which center around X-rays, the electrical phenomena observable in exhausted tubes and radioactivity. The author is himself Fellow of St. John's College and demonstrator in physics at the Cavendish Laboratory. The points of view taken are then those which have grown up in that inspiring atmosphere out of which have unquestionably come more of the influences which have molded modern physics than from any other two places in the world combined. Freshness and originality of treatment are to be expected from such an author, and the expectation is not disappointed. The first two chapters deal with the determination of e/m and e, the third and fourth with the work on positive rays, J. J. Thomson's beautiful photographs being given especial attention. The fifth chapter gives the usual deductions found in a chapter on the nature and size of an electron. The sixth and seventh chapters are entitled the Chemistry of the Model Atom and the Atom in Vibration and represent the best elementary treatment I have seen of atomic models in relation to spectroscopy.

The eighth chapter presents just a touch of the conventional molecular physics in the discussion of Van der Waal's equation, but the last half of the chapter returns to the electron theory of metallic conduction. This subject is treated in the usual way, but unfortunately, I think, without any attempt to explain, or even to state the serious difficulties which the theory encounters. This is the one place in the book where the untrained reader will perhaps obtain a somewhat erroneous impression. The last chapter on the Atom in Dissolution is a very brief survey of the subject of radioactivity. Altogether the book is admirable and contains elements of interest for both the physicist and the general reader.

R. A. Millikan

SPECIAL ARTICLES

MILK EPIDEMICS OF SEPTIC SORE THROAT IN THE UNITED STATES AND THEIR RELATION TO STREPTOCOCCI

IN England epidemics of sore throat, bearing some relation to the milk supply, were recognized as early as 1880 (Rugby). Since then a number of such epidemics have occurred and in those in which the etiology was investigated, streptococci were uniformly found as the infectious agent. In some of these epidemics there were reasons to believe that udder or teat infections were the source of the organisms; in others the evidence seemed to point to a milker or handler as the source.

In the United States the first epidemic of sore throat recognized as having a definite relation to the milk supply appeared in Boston in 1911 and was carefully investigated by Winslow.[1] There is no doubt, I think, that many such epidemics have occurred in the past in this country, as well as in other countries, but on account of the almost universal prevalence of ordinary colds and sore throats their epidemic character and origin was not recognized. Indeed, in the medical literature there are references here and there to outbreaks of severe colds and other similar infections associated with serious and fatal complications, such as peritonitis. It is not unlikely that such epidemics originated from a contaminated milk supply since we know that these milk epidemics are, as a rule, serious infections followed often by severe complications. In the case of milk epidemics of scarlet fever, diphtheria and typhoid fever, it may be pointed out that formerly their possible relation to the milk supply was not recognized or was denied, and only recently, when more intensive studies of such epidemics were made, was their true relation to milk supply established.

Since the Boston epidemic of 1911, similar outbreaks have been reported from Chicago, Baltimore, Boston (1912), Concord, N. H., Cortland and Homer (N. Y.), Wakefield and Stoneham (New York) and Jacksonville, Ill. The number of persons stricken in these various epidemics has been estimated as follows: Boston, 1,400, Chicago 10,000, Baltimore 1,000, Boston (1912) 227, Concord 1,000, Wakefield and Stoneham 1,000, Cortland and Homer 669, Jacksonville 348; making a total of nearly 16,000. Probably many more than this number were affected since the above are all conservative estimates. This number is sufficient to at least give one some idea of the magnitude and importance of this type of infection.

In all, the onset, the character of the symptoms, and the later complications are strikingly alike and, it may be said, they agree in this respect with the epidemics in England. Furthermore, the relation to the milk supply appears to be unquestionable in all. The interesting fact stands out that there is a certain uniformity in the reports in that the contaminated milk, though used perhaps by a small proportion of the people, still furnished a very high proportion (70, 80 or 90 per cent.) of the reported cases. The remainder of the cases probably resulted from personal contact or from some other means.

Streptococci were unquestionably the cause of the disease in all the epidemics, being found abundantly in the throats or in the secretions of the sick persons in all the cases investigated. This fact is of great importance because it establishes definitely the etiology, and since the clinical symptoms in all the epidemics are so strikingly uniform, we may consider these infections as a definite clinical entity. They should, I think, take their place and be considered in text-books in medicine along with other infectious diseases, such as scarlet fever, measles, typhoid fever and the like.

As regards the nature of the streptococci, there is a fair degree of uniformity so far as the reports of the various investigators permit one to judge. They are all virulent, usually highly so, for animals. In general, they correspond, with only slight variations, in their morphology, in their cultural characteristics, and in their biological properties. In certain respects there seem to be some

[1] *J. Inf. Dis.*, 1912, X., 73.

slight differences between these streptococci and the ordinary *Streptococcus pyogenes*, and these differences have been sufficient to lead to the use of the special term *Streptococcus epidemicus* for them. It should be stated that it may be questioned whether or not the differences between them and the *Streptococcus pyogenes* are sufficient to justify such a distinction. They may be simply highly virulent strains of ordinary *Streptococcus pyogenes* whose properties have been modified by animal passage.

In some of the reports, particularly the earlier ones, and this is especially true of the English epidemics, descriptions of the streptococci are not given in detail. In certain instances this could not be done because the epidemic was practically over before its study was undertaken. It is unfortunate that this is so, because it is very important that the organisms from each of these epidemics should be carefully studied in order that the results may be correlated. It may not be out of place here to call the attention of physicians and health officials to the importance of such studies. Especially should the local physicians and health officers in small communities and towns be on the lookout for such epidemics, for it is they who meet these cases early, the time most suitable naturally for the isolation and study of the causative agent. Such physicians and health officers should see to it therefore that a careful bacteriologic study be undertaken as soon as possible. If they have not the means at hand or for any reason do not care to undertake such a detailed study, they should send the material to some laboratory where this can be done. The writer would be glad to examine such organisms with a view to identification and requests any who may desire to do so to send such material to him.

It may be stated that in the future it is probable that the small community will be affected by such milk epidemics more frequently than the larger cities since the milk products are apt to be less carefully handled and pasteurization will less often be required than in larger places.

One of the properties noted in the streptococci from nearly all the epidemics is that of hemolyzing blood when the colonies are grown on human or rabbit blood agar plates. While there has been slight variations in the strains studied, they have been strikingly alike in this respect. By hemolysis is meant that a well-defined wide clear zone appears about the colonies in 24 hours at incubator temperature. It does not mean a slight halo occurring about the colonies nor does it mean a slight narrow ring of cleared media developing perhaps after 48 hours or more as occurs with certain strains of organisms. This property is of great importance because it is a very ready and practical means of differentiating such organisms from the common *Streptococcus lacticus* (*Bact. güntheri*) which are not hemolytic. These latter are practically always present in normal milk, and so far as we know are of no sanitary significance. It should be pointed out that there are other perhaps more reliable but less practical means of determining the hemolytic power of bacteria than the simple plate method. I refer to such methods as those of Lyall[2] and Marmorek[3] which should be used as confirmatory tests, where they are of real value.

It is not to be understood that every hemolytic streptococcus is necessarily virulent or dangerous to man. But finding them in any considerable number in milk should make one very suspicious of udder disease, and such milk should at once be excluded from use.

The question of the source of streptococci causing these epidemics of sore throat is an important one. Two possible sources are recognized: the one bovine—the udder or teats of the cow; the other human—some lesion in the throats, hands, etc., of a milker or handler. It is often a difficult matter to absolutely prove in a given case whether or not the infection is bovine or human in origin. This is because practically identical hemolytic streptococci occur in the diseased udders of cows and also in the throats and on the hands of milk handlers. Furthermore, both streptococcal infections of udders in cows and streptococcal

[2] *Jour. Med. Research*, 1914, XXX., 487.
[3] *Ann. de l'Inst. Past.*, 1902, XVI., 172.

infections in the human are relatively common; consequently, in an investigation of large numbers of cows and of milk handlers, as it is usually necessary to do in studying these epidemics, one is very apt to find instances of one or the other and hence draw conclusions accordingly. On the other hand, the real source of streptococci may be overlooked on account of some hidden focus of infection in the throat or tonsils of a milker which could not be detected in an ordinary throat examination. Or a cow might be suffering with inflammation of the udder and discharging millions of streptococci in the milk and still, as the writer has shown experimentally, the udder may show no physical signs of disease and might thereby escape detection on inspection. For these reasons it is readily seen how one might be misled in his conclusions when looking for the ultimate source of streptococci causing an epidemic.

In the Boston epidemic the source of the streptococci was not clear, Winslow stating that it was probably a carrier. In the Chicago epidemic, certain facts suggest that the origin was bovine, but absolute proof was lacking. Stokes and Hatchell from their investigations of the Baltimore outbreak "feel reasonably sure the infection was caused by streptococci of the epidemicus type from cases of mastitis among the herds supplying the dairy."[4] In the report of the Concord, N. H., epidemic, made by Mann[5] no mention is made of a possible bovine source. There was evidently sufficient opportunity for contamination of the milk by human carriers on the farms supplying the milk. In the Wakefield and Stoneham (N. Y.) epidemic reported by Morse,[6] a very definite connection seemed to exist between the epidemic and a throat abscess in one of the milkers. In the report of the Cortland and Homer epidemic made by North, White and Avery, the statement is made that "two cows having inflamed udders in the herd of Dairy X were undoubtedly responsible for the epidemic of septic sore throat."[7] At Jacksonville, Ill., the epidemic, studied by Dr. J. A. Capps and the writer, was caused by hemolytic streptococci and from two cows supplying milk to Dairy X the same type of organisms were isolated. No suspicious human carriers could be found on the farms or among the milk handlers.

From the above it is seen that bovine and human sources are suspicious, and perhaps each or both at times may be responsible. It is known that human streptococci may be highly virulent for cows[8] and the reverse may also very probably be true. In an analysis of milk organisms, therefore, the fact that hemolytic streptococci have been the cause in probably all the sore throat epidemics centers our attention at once upon this type of streptococcus. As yet there is no evidence that other types have any sanitary significance whatever so far as sore throat or any other human disease is concerned. I therefore call attention to the fact that in any investigation of milk streptococci, whether from the standpoint of pure or applied bacteriology, the relation of the streptococci to hemolysis of blood should be carefully noted. It is well known, of course, that hemolysis may not be an absolutely stable property in any given strain. A strain may occasionally alter its power in this respect just as it may change its fermentative properties under certain conditions. For practical purposes, however, it is of very great value, as I believe every one who has occasion to work with pathogenic streptococci will admit. Furthermore, the fact that the hemolytic property can not be correlated with other properties such as those of fermentation does not detract from its value as a differentiating feature, but rather adds to it.

The question of pasteurization is an interesting one in relation to these infections. In the case of at least four of the epidemics in this country the infected milk had been pasteurized by the "flash" method and the evidence in all indicated quite clearly that the milk was contaminated before pasteurization. Nothing further need be said, therefore, con-

[4] Public Health Reports, 1912, Vol. 27, p. 1923.
[5] *Jour. of Inf. Dis.*, 1913, 12, 481.
[6] *Am. Jour. Pub. Health*, 1914, 4, 506.
[7] *Jour. Inf. Disease*, 1914, 14, p. 132.
[8] Davis, *Jour. Inf. Dis.*, 1914, 15, 135.

cerning the absolute inefficiency of the "flash" method. The harm it may do by giving the people a sense of false security is also self-evident. In the remaining epidemics the milk was consumed raw. It would seem that our only safeguard against such epidemics is efficient pasteurization not only of the milk and cream, but also of the material entering into the manufacture of other milk products. It is a point of some importance that it is not uncommon for firms to sell pasteurized milk, but to sell cream in the raw state. The latter of course may be even more dangerous than milk.

The question as to what constitutes efficient pasteurization for streptococci is one that evidently requires further study. It is commonly stated in the literature that pathogenic streptococci are killed at relatively low temperatures (52°–54° C. for 10 minutes Sternberg). Undoubtedly for many strains this is altogether too low. The recent work of Ayers and Johnson[9] indicates that the thermal death point of typical streptococci varies considerably and one of 22 strains studied by them resisted heating for 30 minutes at 62.8° C. (145° F.), the usual temperature for pasteurizing. Furthermore, their viability in milk and milk products should be carefully studied since we know the media may exert an important effect on the resistance of organisms to heat. The pasteurization process may therefore have to be modified accordingly to meet these demands.

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The Artificial Fertilization of Queen Bees

In July last, the senior writer called the attention of the junior writer to the desirability of attempting some work in bee culture, with the object of securing pure-bred queens. One of the lines of work decided upon was that of artificial fertilization of queens. In spite of the lateness of the season, it seemed advisable to begin work at once and eight newly emerged queens were secured before the end of the queen-producing season.

In six of the experiments, we suffered failures from natural causes; robber bees killed three and the workers refused to accept three. In a seventh case, the queen died as a result of an infection probably set up at the time of fertilization.

In an eighth experiment, apparent success seems to have followed artificial fertilization, and whatever the nature of this may be, it seems of sufficient interest to be recorded, awaiting, in the meantime, the next season for further attemps at confirmation. This queen emerged from her cell on July 23, 1914. Both wings were so rudimentary as to be almost unnoticeable. She was kept in a 3-frame nucleus, in which no drones were present and with a queen excluder applied to the entrance. On July 28, the seminal vesicles and spermatophore of a drone, which was captured in flight near one of the hives, were dissected out, teased apart, and contents diluted to facilitate manipulation. The fluid containing spermatozoa was then carefully injected through the genital opening of the queen. After this was done she was replaced in a queenless and droneless nucleus with queen-excluder applied to the hive.

By August 4, the ovaries showed considerable development, as indicated by the size of the abdomen, and on August 18 she began to deposit eggs, continuing to do so up to the time of writing, although normal queens had ceased to lay eggs for about a month. This was due probably to the stimulation given this swarm by feeding. To date, at least 3,000 eggs have been laid. The remarkable thing is that all the eggs have produced worker bees except four, which produced drones. In every respect the brood, capping of the cells, and the resulting worker bees are perfectly normal.

At present, the swarm is being strengthened and prepared for winter, so that studies of this remarkable queen may be continued next season.

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[9] *Jour. of Agricultural Research*, 1914, 2, p. 321.